VOL. XXVII. — No. 9. SEPTEMBER 1950.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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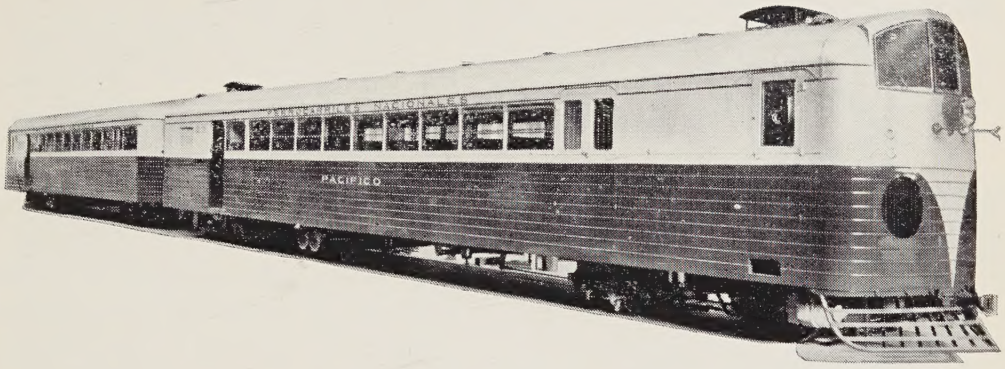

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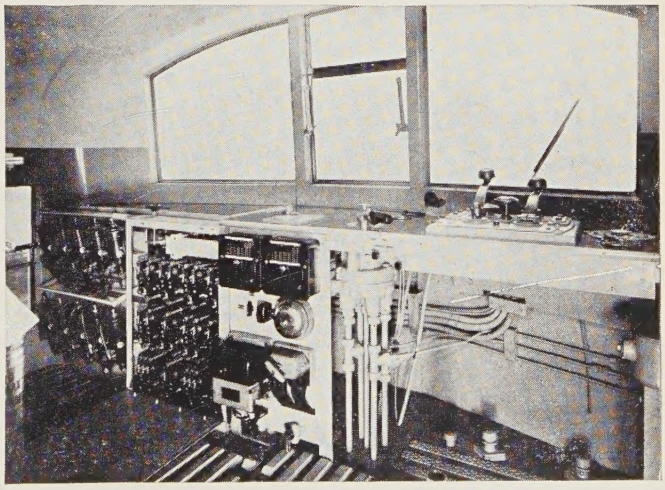

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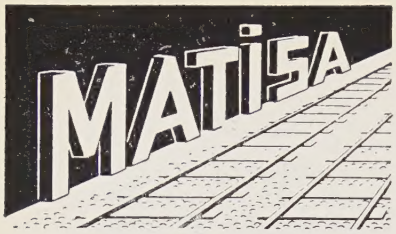

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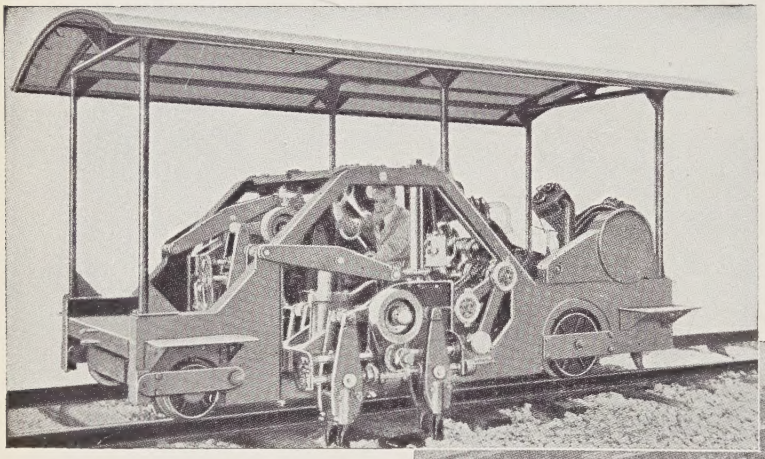

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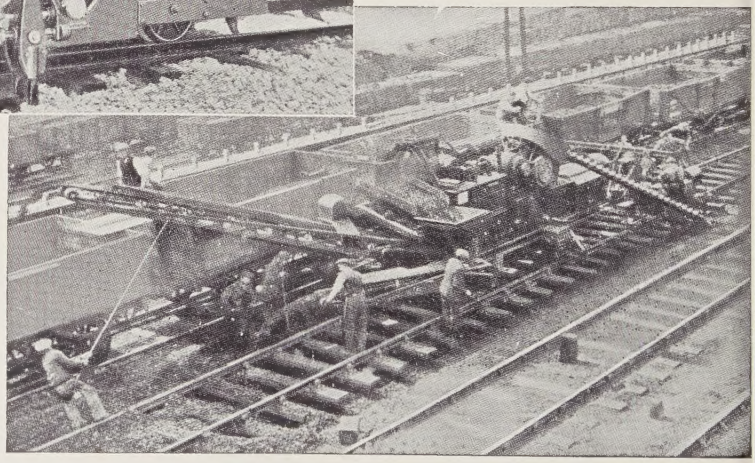

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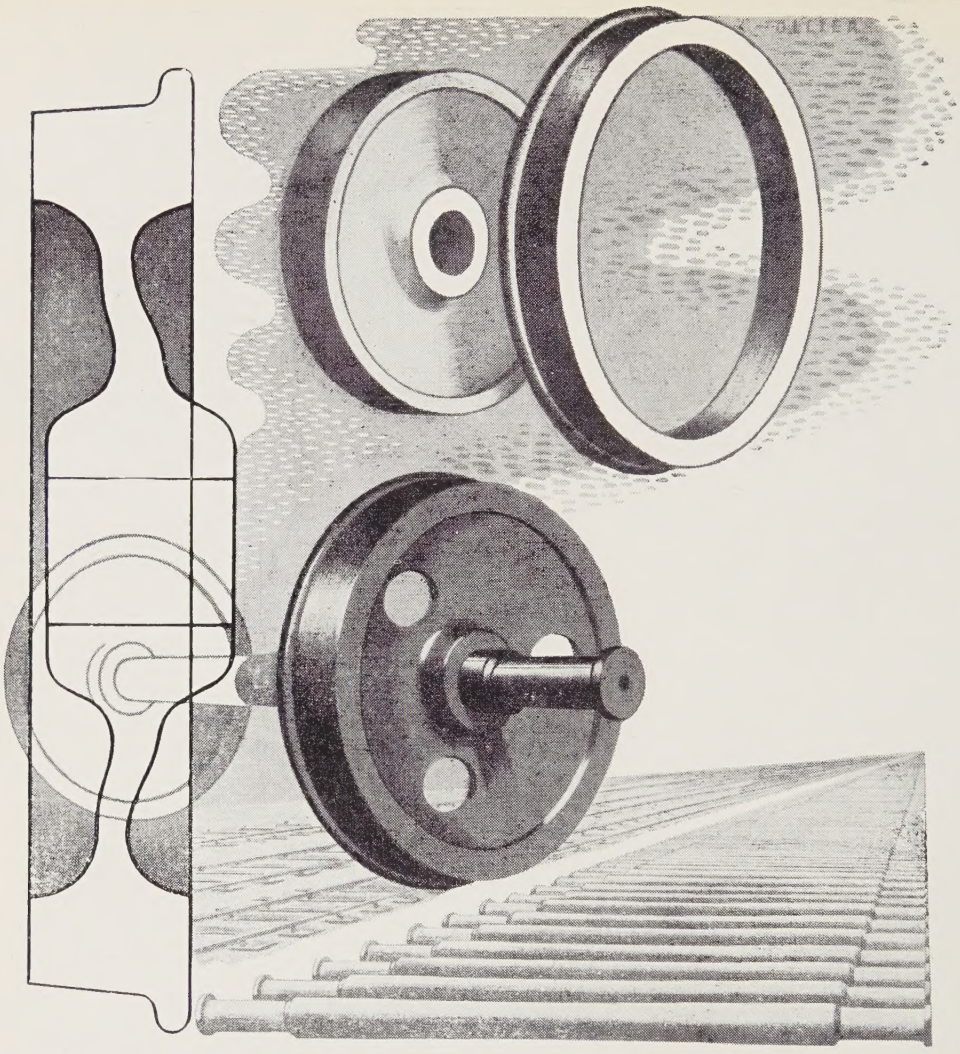

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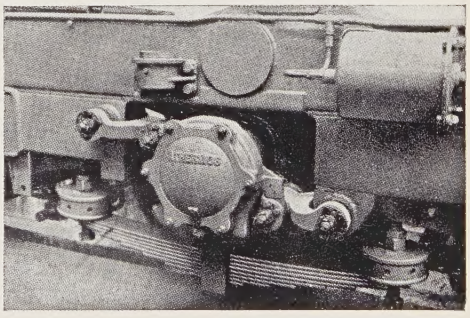

S. N. C. F. electric locomotive C. C. n° 7001 Details of the suspension

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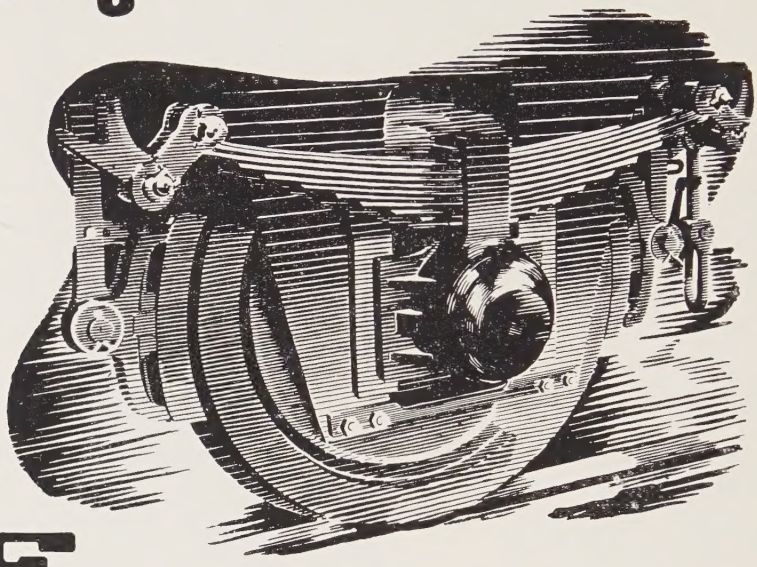

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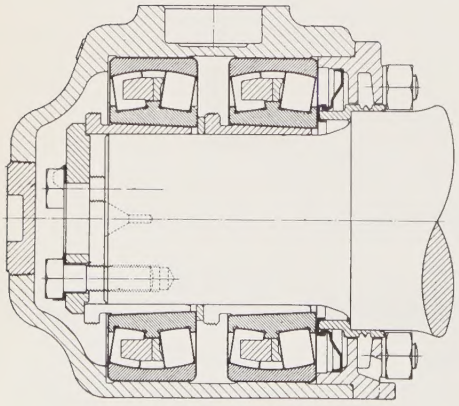

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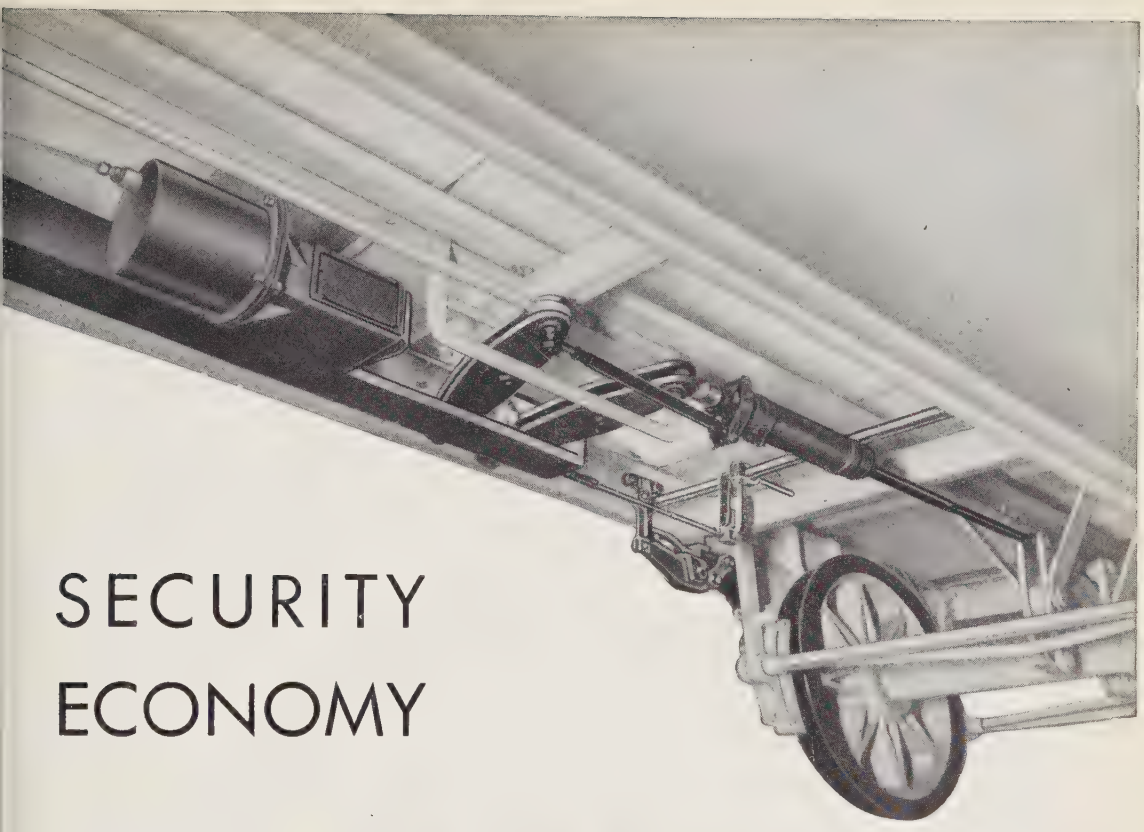

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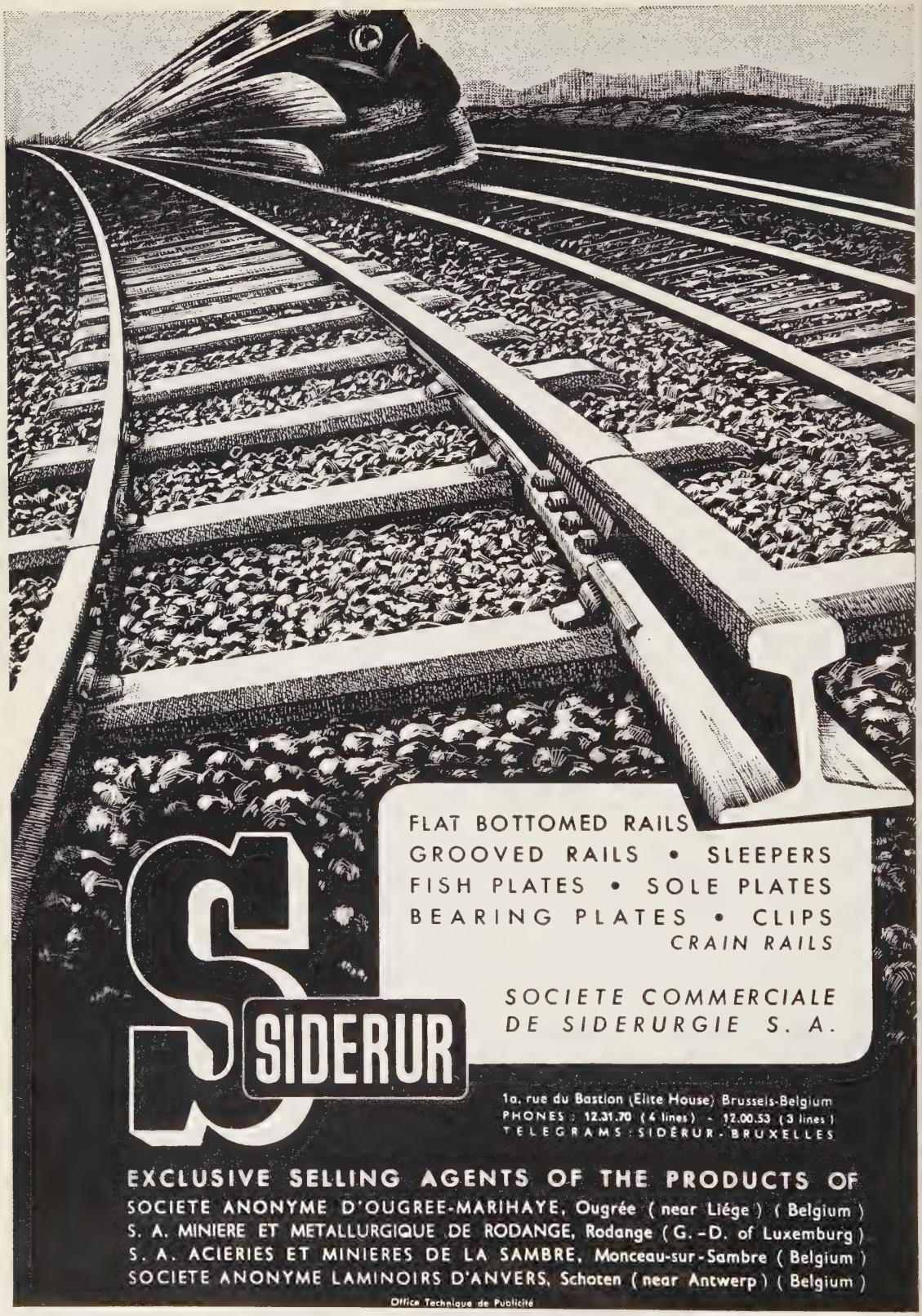
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Bulletin of the International Railway Congress Association

CONTENTS OF THE NUMBER FOR SEPTEMBER 1950

1950 **625** .2

Bull. of the Int. Ry. Congr. Ass., No. 9, Sept., p. 1861.

MARTINELLI (Mario). — **The comfort of passengers in coaches, railcars and electric motor coaches : sound proofing : lighting; heating, air conditioning, ventilation; thermic insulation; upholstery; running stability (type of bogie and suspension).** (Question IV, 15th Congress). Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey, Yugoslavia).* (6 000 words, tables & fig.)

1950 **624** & **691**

Bull. of the Int. Ry Congr. Ass., No. 9, Sept., p. 1887.

POLSONI (G.). — **Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.** (Question I, 15th Congress). Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey and Yugoslavia).* (15 000 words, tables & fig.)

1950 **621** .431 .72 & **625**. 616

Bull. of the Int. Ry. Congr. Ass., No. 9, Sept., p. 1927.

DIEGOLI (M.). — **Change over from steam locomotive traction to Diesel traction.** (Question XIV, 15th Congress). Report *(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Denmark, Finland, France and Colonies, Luxemburg, Greece, Italy, Netherlands and Colonies, Norway, Poland, Portugal and Colonies, Rumania, Spain, Sweden, Switzerland, Syria, Turkey and Yugoslavia).* (20 000 words, tables & fig.)

1950 **625** .2

Bull. of the Int. Ry. Congr. Ass., No. 9, Sept., p. 1995.

WEBERG (O. G.). — **The comfort of passengers in coaches, railcars and electric motor coaches : sound proofing; lighting; heating, air conditioning, ventilation, thermic insulation; upholstery; running stability (type of bogie and suspension).** (Question IV, 15th Congress). Supplement to Report. (2 300 words, 1 table & fig.)

1950 **625** .143 .4

Bull. of the Int. Ry. Congr. Ass., No. 9, Sept., p. 2001,

LEDUC (O.). — **Rail-joints : improvements in fish-plated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.** (Question II, 15th Congress). Supplement to Report. (1 600 words.)

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CONTENTS OF THE NUMBER FOR SEPTEMBER 1950.

CONTENTS.	Page.
I. **The comfort of passengers in coaches, railcars and electric motor coaches :sound proofing; lighting; heating, air conditioning, ventilation, thermic isolation; upholstery; running stability (type of bogie and suspension).** (Question IV, 15th Congress). Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey, Yugoslavia)*, by MARIO MARTINELLI	1861
II. **Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.** (Question I, 15th Congress.) Report *(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey and Yugoslavia)*, by M. G. POLSONI	1887
III. **Change over from steam locomotive traction to Diesel traction.** (Question XIV, 15 th Congress). Report *(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Denmark, Finland, France and Colonies, Luxemburg, Greece, Italy, Netherlands and Colonies, Norway, Poland, Portugal and Colonies, Rumania, Spain, Sweden, Switzerland, Syria, Turkey and Yugoslavia)*, by M. DIEGOLI	1927

CONTENTS *(continued)*. Page.

IV. **The comfort of passengers in coaches, railcars and electric motor coaches : sound proofing; lighting; heating, air conditioning, ventilation, thermic insulation; upholstery; running stability (type of bogie and suspension).** (Question IV, 15th Congress). Supplement to report by O. G. WEBERG 1995

V. **Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps : determination of standard allowances.** (Question II, 15th Congress). Supplement to report by O. LEDUC. 2001

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Vol. XXVII. — No. 9. September 1950.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .2]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION IV.

The comfort of passengers in coaches, railcars and electric motor coaches :

Sound proofing;
Lighting;
Heating, air conditioning, ventilation, thermic isolation;
Upholstery;
Running stability (type of bogie and suspension).

REPORT

(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey, Yugoslavia),

by Mario MARTINELLI,

Ingénieur, Inspecteur en Chef au Service du Matériel et de la Traction des Chemins de Fer de l'Etat italien.

FOREWORD.

The present report was based on the replies to the questionnaire received from the following Administrations :

Greece : State Railways.
Italy : State Railways.
Portugal : Portuguese Railway Co.
Mozambique : Harbours, Railways and Transports.
Rumania : Rumanian Railways.
Sweden : Union of Swedish private Railway companies (Oxelösund-Flen-Vastmanland and Stockholm-Roslagen Rys.)
Turkey : Turkish State Railways and Harbours.
Spain : Spanish National Railways.

Unfortunately, not many replies were received; but in view of the short time that remains before the actual date of the Congress, we could not wait any longer. If any interesting replies come in later on (as we very much hope they will) we will be able to include them in a supplement to the present report.

* * *

A. Sound insulation.

1. *Steps taken to lessen noise.*

Wheels with elastic packing (rubber) between the tyre and the core have been tried by several Administrations. It was found that with only a small amount of

elasticity this method was not very effective, whereas if the elasticity was too great, the rubber got too hot owing to the great frequency in the reversal of the stresses.

However in Mozambique, the well known Michelin railcars are used which have pneumatic tyres of the same make. The regular working of the electric safety installations on the line is assured by shoes fitted with flexible blades.

Other sources of noise are the brake rigging, the bellows, roof sheeting, etc.

To stop the noise due to the vibrations of the brake rigging, the latter is simplified as much as possible. On the Italian rail motor coaches, brake rigging has been reduced to the minimum by using a single brake cylinder per wheel, while on the coaches the horizontal stays are carried by small links or are taken through rubber sleeves inside a metal tube.

As regards the bellows on the Italian rail motor coaches (very difficult from the point of view of noise reduction owing to the arrangement of the stays on the inside), everything possible is done to keep all the parts permanently under tension, and the joints are fitted with rubber bushes.

On nearly all the Railways the roof sheeting is covered with spray-asbestos or cork to deaden the noise. To stop the wooden panelling rubbing together, on the Italian coaches a thin layer of felt is inserted to prevent direct contact.

To reduce the noise from the internal combustion or electric motors, no special measures are taken. Particular care is taken, however, to obtain perfect balance in the motor itself. As regards the gears, helicoidal teeth are used for railcars and ordinary teeth with very carefully checked profiles for the rail motor coaches.

2. *Steps taken to damp the propagation of noise inside the vehicle.*

Nearly all the Administrations interpose several fittings of rubber or similar material between the wheels and the vehicle; these generally take the form of inserts below the body supports, and sometimes, particularly in the case of railcars and rail motor coaches, definite components completing the spring suspension. Fig. 1 shows an example of the extensive use of rubber in the suspension of an up-to-date rail motor coach on the Italian State Railways. Rubber has also been used in the axle box guides.

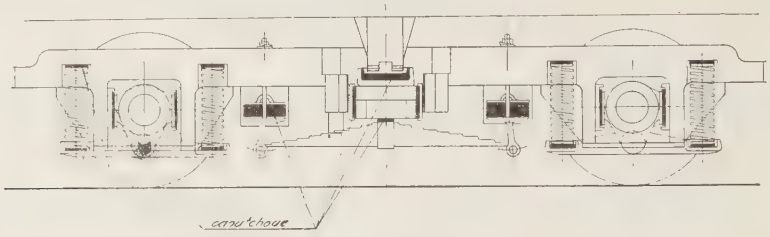


Fig. 1. — Bogie of a recent rail motor coach of the Italian Railways with rubber insulation in the suspension.

On the up-to-date stock of the Italian State Railways, the floor is insulated by means of glass wool 30 mm (1.18 in.) thick, and the walls and ceiling by spray asbestos 12 mm (0.47 in.) thick or 4 mm (0.16 in.) of cork.

Similar methods are used on the rail motor coaches and railcars. In the high speed electrotrains, insulation is also helped by double windows, which are an advantage especially when running through tunnels. The other Administrations use

more or less the same materials for sound insulation (Alfol, Isoflex, Bostik, etc.).

On railcars and rail motor coaches it has been found that for good insulation the motor inspection holes in the floor must be done away with or reduced to the minimum.

To stop the propagation of the noise of the internal combustion engines of railcars it is usual to carry the actual engine on silent-blocks or very flexible rubber blocks, and to protect the exhaust pipe by means of some good sound insulation. On several railcars the exhaust pipe is taken through the roof. The motors are fitted as far as possible in compartments separate from the public part of the coach, or under the floor as in the up-to-date railcars with horizontal cylinder engines. In this case the floor above the motors is insulated with special care and the inspection holes reduced to the minimum.

If the engines project into the vehicle, they are protected by special anti-noise casings (for example on the FIAT railcars of the Italian State Railways and the railcars of the Rumanian Railways) with glass wool, felt, cork, etc. These are very effective.

3. *Details concerning sound insulation inside the vehicles.*

Measurements made on the Italian State Railways vehicles gave the following results :

— Up-to-date 1st and 2nd class coach at a speed of 100 km/h. (62 m.p.h.) out in the open : 75 80 Dc; in tunnels 83 ÷ 88 Dc.

— Fast electrotrain with double windows : at a speed of 150 km/h. (93 m.p.h.) out in the open 73 ÷ 77 Dc; same speed in tunnels 77 ÷ 80 Dc; standing, with the air conditioning equipment working : 71 ÷ 73 Dc; at a speed of 150 km/h. when the air conditioning equipment is not working : 70 ÷ 73 Dc.

B. Lighting.

1. *Source and characteristics of the electric current used for lighting.*

Several of the Administrations which replied use 24 V direct current to feed the lamps supplied from accumulators which are usually charged by one or several dynamos on the train itself. In general, it is considered preferable to charge the accumulators on the train either because this makes the current more readily available or for economic reasons.

The Italian State Railways are the only ones to recharge accumulators in fixed plants, but they have already made provision for charging them on the train. The Spanish Railways make use of fixed installations in the main stations for giving an extra charge in the case of trains which make long stops there.

Normally the current for lighting is produced by one or several generators per coach. Sometimes however a single generator is used to supply the whole rake or group of vehicles.

The Swedish private Railways use 125 V. D. C. motor-generators on certain suburban trains, fitted on the locomotive or power unit. These supply current to the whole rake and work without accumulators.

The Portuguese Railway Co. makes use, on some lines, of groups of three vehicles supplied by a single generator. The Italian State Railways use rail motor coaches with one or two trailers supplied by a single generator fitted on the motor unit and driven by the axles, or in the most recent vehicles, a 3 000 V electric motor.

In this connection a typical example is furnished by the most recent fast electrotrains of the Italian State Railways in which the necessary power for the air conditioning equipment and the fluorescent lighting is supplied from a three phase 220 V 50 Hz alternator driven by a 3 000 V electric motor.

ADMINISTRATION	Type of vehicle	Type of accumulator	Capacity of accumulator
GREECE *State Railways*	Coaches	Lead and nickel-iron (2)	200 Ah
ITALY *State Railways*	Coaches	Lead (3)	500 to 800 Ah
	Rail motor coaches	Lead (3)	260 Ah
		»	»
	Railcars	Lead (3)	220 to 440 Ah
PORTUGAL *Portuguese Railway Cy.*	Coaches	Cadmium-nickel	200 Ah
SPAIN *Spanish National Railways*	Coaches	Lead and nickel-iron	120 Ah (6)
MOZAMBIQUE *Railways and Transports*	Coaches	Alcaline Lead (7)	150 Ah 670 Ah (7)
RUMANIA *Rumanian Railways*	Coaches Railcars	Lead »	220 Ah 400 Ah
SWEDEN *Private Railways Union*	Coaches	« Nife »	200 Ah
TURKEY *State Railways*	Coaches	Cadmium-nickel	120 to 240 Ah

(1) Total power of all the generators of the vehicle.
(2) The Greek Railways are proposing to standardise the use of nickel-iron accumulators.
(3) Experiments are also being made with cadmium-nickel accumulators.
(4) The 7 kW dynamo is intended to supply a rail motor coach and two trailers.

Power dynamos (1)	Revs per minute of the generators	Type of drive	Method used	Type of regulator
1.2 kW	270 — 2 200	By the axles	Belt	—
rged by fixed installations.				
÷ 3.5 kW	500 — 2 000	By the motor axles	Chain or gears	Pintsch
kW (4)	2 000 — 2 300	By a 3 000 V motor		Special exciter
÷ 2.4 kW	600 — 1 200	By the internal combustion engines	Belt	Third brush Tyrril. Special exciter
2 ÷ 3 kW	—	By the axles	Belt or mechanical drive	Dick with contactors Dick with mercury column Liberty (5) Pintsch Stone
÷ 4 kW	—	By the axles	Belt	Brown-Boveri Stone
750 W 3 kW (7)	— —	By the axles By the axles	Belt Belt	— —
1 kW ÷ 5.5 kW	— —	By the axles By the motors	Belt Trap. Belt	Dick Dick
2.7 kW	450 — 2 700	By the axles	Cardan drive	Carbon plate
1.7 kW	300 — 2 000 350 — 2 400	By the axles By the axles	— —	Dick GEZ Stone

5) The Portuguese Railway Co. states that the best results have been obtained with the Liberty, Pintsch and ne types.
6) 36 V battery.
7) The battery and dynamos also supply current for the air conditioning equipment in this case.

ADMINISTRATION (1)	Number and power of lamps per compartment			Night lights
	1st class	2nd class	3rd class	
GREECE	2 × 40 W	2 × 25 W	2 × 15 W	10 W blue
ITALY	2 × 40 W	2 × 40 W	2 × 20 W	5 W blue
PORTUGAL	2 × 40 W	2 × 25 W	2 × 15 W	15 W blue or lamps normal put in series
SPAIN	—	—	—	Blue lamp or resistan in series with the ordinary la
MOZAMBIQUE	9 × 15 W	5 × 15 W	3 × 15 W	Blue lamp
RUMANIA	2 × 20 W 2 × 25 W	2 × 20 W 2 × 25 W	2 × 20 W 2 × 25 W	Blue lamp
SWEDEN	—	—	—	—
TURKEY	3 × 40 W	2 × 40 W	2 × 40 W	10 W blue

(1) For the names of the Administrations, see Table I.
(2) The Spanish Railways report that one fault of reading lamps behind the passengers is that they c the passengers seated opposite.

Reading lamps	Steps taken to protect the sight from direct light from the filaments	Emergency lighting
None	None	Candles
None	Opaque glass ceiling lights in 1st and 2nd classes	None
Exceptionally	Diffusers in 1st and 2nd classes	From the nearest coach
In 1st class and sleeping cars (2)	Diffuser shades	From adjoining coaches
In sleeping cars	Pearl bulbs. In pearl glass casings in 1st class	Petrol lamps in 3rd class only
In 1st class	Opaque or opaline bulbs, and opaline shades	None
Exceptionally	Opaque globes or screens	From the A.C. system By emergency 6 V batteries By acetylene gas
None	Opaque bulbs	From adjoining coaches

On some Railways (Spain, Turkey) the vehicles are fitted with electric couplings so that the whole rake can be lit even if the generator is not working.

Table I sums up the characteristics of the accumulators and generators used by the different Administrations.

2. *Lighting equipment.*

The Administrations who replied to the questionnaire mostly use incandescent lamps to light the vehicles.

Table II gives a general idea of the lighting used on the most up-to-date stock of the different Administrations.

The private Swedish Railways use fluorescent lamps with cold cathode on their most recent vehicles. The Italian State Railways use fluorescent lamps with hot cathode on the most recent fast electrotrains and « Breda » railcars.

All the Administrations make provision for the passengers to be able to put out or reduce the lighting by means of switches. Such switches are not however provided in the case of rail motor coaches, and railcars divided into one or two large compartments.

In general there does not seem to be any need to protect the lamps against shock or theft. However, the fittings used are not of the standard mains type, and the lamps are carefully sited.

In Spain however diffuser shades are fitted with an armature closed by means of a special kind of key; in Italy the plug-in part of the lamp is fitted with a special band which makes it impossible to withdraw the lamp once it has been put in without breaking the glass.

3. *Details concerning the lighting of vehicles.*

A few Administrations have measured the intensity of the lighting inside their vehicles.

The Turkish Railways found by measurement that the intensity of the lighting in their 1st and 2nd class coaches was 50 Lux; the Spanish Railways found it to be 20 to 30 Lux, but they require it to exceed 40 Lux in the case of new stock; the private Swedish Railways measured $50 \div 75$ and even 80 Lux; the Italian State Railways $50 \div 60$ Lux in the 1st and 2nd class coaches and $40 \div 50$ in the 3rd class coaches, but they stipulate that it shall be $60 \div 70$ in the case of the new dynamo coaches.

On the fast electrotrains of the Italian State Railways lighted by fluorescent lamps, an intensity of 200 Lux and over has been measured. This however is exceptionally high, and the Italian State Railways have no intention of reaching similar values in their ordinary coaches. They are only considered suitable for the luxury trains.

C. Heating, ventilation, air conditioning, heat insulation.

1. *Steam heating.*

One of the greatest difficulties with steam heating installations is to get the heating to function uniformly throughout all the coaches of very long trains. The steps generally adopted to achieve this are increasing the feed pressure in the conduit and using large diameter pipes carefully insulated.

In Italy, a pressure of 7 atm is used, while in Spain it is 6 atm, in Sweden $4 \div 6$ atm, in Greece 5 atm, in Turkey and Rumania 4 atm and in Portugal 2 to 3 atm.

In some countries special methods are used apart from those mentioned above.

In Turkey, on the very long trains a heating van is put at the end of the train.

In Sweden (private Railways), there are « steam traps » on the main conduit hoses and at the end of the long trains there are cocks so regulated that the steam circulates throughout the rake.

No Administration makes use of any method with recovery of the condensation water, nor of hot air heating.

The radiators in the corridors of compartment coaches are either under the windows (Rumania, Spain) or against the inside partitions (Italy).

On some Railways (Turkey, Portugal) heating pipes are used instead of radiators.

In Sweden the main conduit itself acts as a radiator, being sited along the corridor floor.

2. *Electric heating.*

The Mozambique Railways use electric heating on vehicles equipped with air conditioning. In view of the local climate (minimum temperature 12° C = 53.6° F) the radiators for heating are supplied from 48 V accumulators.

The Swedish private Railways use electric heating at 800 ÷ 1 000 V A. C. or 1 500 V D. C. according to the system. They make use of radiators fitted under the seats, and on the most recent vehicles, the pulsated air system. The heating installations are based on an outside temperature of — 30° C (— 22° F) and a speed of 120 km/h. (75 m.p.h.). They vary between 20 and 32 kW according to the type of vehicle. The corridor radiators are fitted along the floor.

The Rumanian Railways use 1 500 V D. C. and 1 000 V A. C. electric heating for the international services only.

The Spanish Railways only use electric heating on their rail motor coaches. The installation which consists of three series per coach (each series consisting of 9 radiators) is supplied at 1 500 V D. C. The power is 12 kW in order to maintain the inside temperature at 15° C (59° F) when it is 0° C (32° F) outside, at a speed of 85 km/h. (53 m.p.h.). The radiators are fitted under the seats. The Administration is not satisfied with this arrangement, as the seats get too hot even though they are insulated from the radiators.

The Italian State Railways on the other hand use electric heating extensively, both on their rail motor coaches, and on the ordinary coaches running over the electrified lines. The nominal voltage is 3 000 V D. C.

In the coaches radiators are used, fitted under the seats. Each compartment is fed directly at 3 000 V, quite separately from the others. The radiators are fitted with an air circulation duct behind the back of the seat (Fig. 2). The power of the installation is about 32 kW per coach. This is designed for an outside temperature of — 10° C (14° F) and a speed of 120 km/h. (75 m.p.h.) (1). The electric power which the accumulators have to supply to work the contactors is very small. Actually the said contactors are so designed that they only take current when they are operated.

The corridors are heated by means of hot air heated by sufficiently large radiators sited in the compartments. Consequently there are no radiators to take up space in the corridors (Fig. 2).

In the rail motor coaches the electric heating system consists of 3 000 V radiators in one or two series per coach. The power of the installation is about 28 kW, designed for outside temperatures of — 10° C (14° F) and a speed of 140 km/h. (87 m.p.h.). In the earliest rail motor coaches the radiators were fitted under the seats. But as the same drawbacks of overheating of the seats reported by the Spanish Railways were experienced, in the recent cars the radiators have been fitted along the side partitions. Ducts in the space between the inside and outside sheeting lead off some of the hot air towards the upper part of the coach.

For the electrotrains fitted with air conditioning, see below.

3. *Other heating systems.*

Other heating systems, neither steam nor electric, are only used on railcars and their trailers.

(1) An excess of power is purposely provided so that the vehicles can be heated up very quickly at the beginning of the journey, and to meet the requirements of colder climates when they travel into other countries.

The Italian State Railways use the engine cooling water or the exhaust gases to heat their railcars. This system has the drawback of providing insufficient heating on downhill runs. To overcome this difficulty in some of the terminal stations fixed hot air preheating systems are used : hot air from suitable stoves is introduced into the railcars by means of flexible pipes.

To heat the trailers (now under construction) a special heavy oil boiler has been provided, which is entirely automatic. It has an output of 44 000 cal/h.

4. *Regulation of the heating.*

On nearly all the Railways covered by the present report, the passengers regulate the steam heating by cutting out one or both radiators in the compartment.

The Rumanian Railways even use this same system with electric heating.

In Italy, on the contrary, the electric heating is regulated automatically by a thermostat inside the compartment. The graduation can be regulated to some extent by the public. This controls the temperature to within ± 1° C.

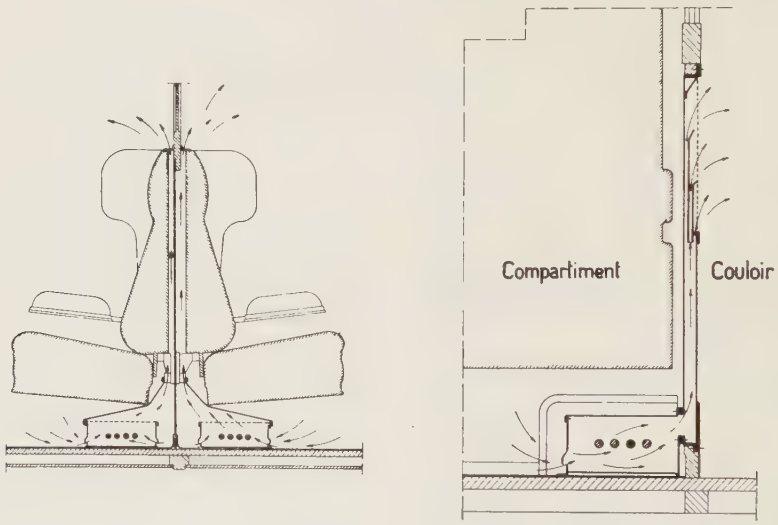


Fig. 2. — Italian Railways coach — arrangement of the electric radiators and ducts for the circulation of the air.

The Rumanian Railways have given up the heating system in which the engine cooling water was used, and have fitted boilers on both the motor and trailing units.

The Swedish private Railways heat their railcars with the engine cooling water, sometimes in conjunction with a coke boiler. They use coke boilers on the trailers.

On the Swedish private Railways, the heating is regulated by the train staff and also by the passengers.

On the most recent coaches fitted with supplementary pulsated air heating, this is regulated automatically by thermostat.

In Turkey the heating is regulated in some recent coaches by three different devices, i.e. :

— simple regulation by hand;

— automatic precision regulation;
— regulation by hand in the different compartments.

The simple regulation by hand is done by the train staff according to the outside temperature, by means of a key, to five different degrees. The automatic precision regulation takes place by means of a device consisting of two pipes fixed inside and an aluminium regulator exposed to the outside temperature.

On the railcars and rail motor coaches the regulating is generally done by the train staff, and sometimes automatically by thermostat.

On the Italian State Railways rail motor coaches, the electric heating is regulated by means of a special device which switches the heating on or off automatically.

The driver is able to alter as necessary the ratio between the length of the on and off periods.

5. *Ventilation.*

To ventilate the vehicles, nearly all the Administrations make use of special air-extractors worked by the current of air produced by the running of the train. They are sited on the roof of the vehicle or along the body sides under the windows.

There are however some forced ventilation installations using fans.

The Swedish Railways use two electric fans on some coaches, at the ends of the vehicle, which drive the air into the compartments through pipes along the floor. The air is heated in winter.

The Portuguese Railways use fans which draw the air in and also expel it, on the American-built rustless steel coaches.

On vehicles fitted with air conditioning, which will be dealt with below, there is necessarily forced ventilation.

6. *Air conditioning.*

Amongst the Administrations who replied, air conditioning is used on the Mozambique, Rumanian and Italian State Railways only.

In Mozambique « Stone » air conditioning equipment is used. The cooling capacity is 11 000 frig/h. approx. The inside temperature can be maintained at 19° C (66° F) with a relative humidity of 50 % when the outside temperature reaches 32° C (89° F) with a humidity of 80 %. The windows are fixed. The installation is worked by electric power supplied by an 18 kW dynamo driven from the axles.

In Rumania there are some railcars equipped with air conditioning. The cooling equipment uses freon ($C Cl_2 F_2$). The inside temperature can be maintained at 25° C (77° F) when the outside temperature is 35° C (95° F). The compressor is driven by a motor. The windows can only be opened by the train staff.

In Italy the fast electrotrains are fitted with air conditioning.

During the winter the ventilation air is taken in entirely from outside. It is heated by means of electric radiators fed at 3 000 V. The air is renewed in this way at the rate of approximately 25 m³/h. (883 cub. ft. per h.) per passenger, corresponding to 1 250 m³/h. (44 143 cub. ft. per h.) per coach. The heating of the coaches is also supplemented in very cold weather by electric radiators fitted under the seats. This makes it possible to heat the middle of the coach without having to introduce air at too high a temperature. The heating capacity is 24 kW per coach, 16 kW being required for the heating of the air. The equipment makes it possible to maintain the inside temperature at 18° C (64° F) when the outside temperature is — 10° C (14° F) and the speed is 160 km/h. (99 m.p.h.).

At other times the renewal of the air can be considerably accelerated, up to a value of approximately 80 m³/h. (2 825 cub. ft. per h.) per passenger, corresponding to 4 000 m³/h. (141 259 cub. ft. per h.) per coach. This high rate makes it possible to deal with the rather high temperatures which occur in certain parts of Italy in the

spring and autumn, without having to switch on the cooling equipment. The movement of the air, caused by its frequent renewal, makes it possible to stand relatively high temperatures without discomfort.

During the summer, the ventilation air is cooled by a cooling system using methyl chloride (CH_3Cl).

The output of the inlet air ducts is maintained at a maximum value of 4 000 m^3/h. per coach, in order to obtain a rapid movement of the air, which minimises the feeling of heat. Part of this air, however, is collected from within the coach itself (recirculated air) and consequently the renewal of the air is once more reduced to its minimum value of 1 250 m^3/h. per coach, without reducing the speed at which air is drawn in. The power of the installation is therefore about 20 000 frig/h. per coach. The inside temperature can be maintained at about 26° C (79° F) with a relative humidity of 50 % when the outside temperature is 34 — 35° (93° to 95° F) with a humidity of 60 %.

The installation is regulated by the train staff, but in recent installations, automatic regulation of the whole equipment has been provided, but it is too early to express an opinion on the results obtained.

The above details refer to the Italian built equipment (Dell'Orto). Recently an electrotrain fitted with « Stone » equipment has been put into service with good results.

The windows of the electrotrains are fixed. There are however four small windows per coach which can be opened by the train staff if necessary. However, in the hot season this has been found to be insufficient.

The power needed to operate these installations is taken from the overhead line at 3 000 V D. C.

7. *Heat insulation.*

For heat insulation the same materials as are used for sound insulation are generally employed (cork, Bestik, Celatex, Alfol, Isoflex, Spray-asbestos, glass wool, etc.). Several of these materials are often used together to achieve the desired end.

Double glass windows are used in Italy exclusively on the electrotrains fitted with air conditioning equipment, whereas in Sweden they are used on nearly all the stock. In Rumania a few railcars have a second fixed glass only some 40 cm (15 in.) high, intended to protect passengers from draughts.

The Administrations concerned did not give us any interesting data on the coefficients of heat transmission for the materials used, nor on the amount of insulation provided in recent vehicles. It may be reported however that on an Italian electrotrain one of the coaches, insulated with Alfol and fitted with double windows, the calories transmitted to the outside per hour and per degree of temperature increase are about 500.

D. Internal fittings.

1. *Seats.*

On the 1st and 2nd class coaches upholstered seats are provided with head and arm-rests. The latter can normally be lifted up and sometimes pushed back into recesses in the back of the seat. In some countries (Greece) the backs are separate from the head-rests.

In 3d class coaches, upholstered seats are provided nowadays with upholstered head-rests as well, separate from the back. In carriages used for short distance journeys wooden seats are still provided, sometimes covered with plastic material or linoleum (Italian State Railways).

Figs. 3 and 4 are diagrams of recent Italian coach seats. The seats in coaches belonging to the other Administrations are very similar.

There are however some types of seats of very different design to the above. These are the reversible seats of the Portuguese American-built coaches of the « Budd »

type (Fig. 5) and those on the recent coaches of the Swedish private Railways (Figs. 6 and 7).

On railcars and rail motor coaches generally the seats have low backs and no headrests, but when such vehicles are intended for long distance runs bigger and more

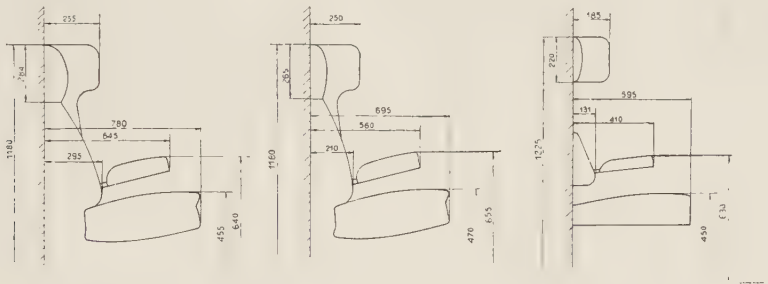


Fig. 3. — Diagrams of the seats on recent Italian coaches.

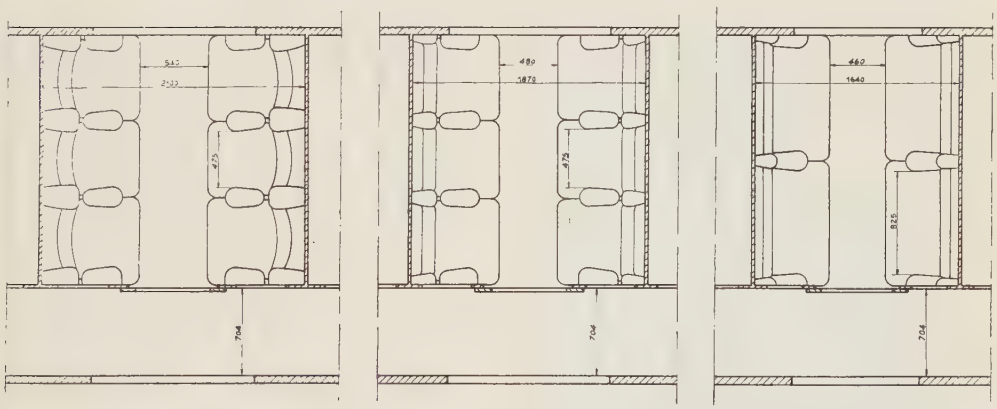


Fig. 4. — Diagrams of the compartments on recent Italian coaches.

comfortable seats are provided. Figs. 8 and 9 show the standard seat used on the recent rail motor coaches and railcars of the Italian State Railways.

The upholstery generally consists of springs and hair. Sponge rubber has not given good results.

The cover generally consists of velour in the 1st and 2nd class carriages (Italian, Rumanian, Greek Railways). The Spanish and Portuguese Railways however use cloth or linen; the Turkish Railways plastic materials, and the Mozambique Railways, leather.

In 3rd class carriages plastic materials or pergamoid are used in nearly every case. The Swedish private Railways use corded material, moquette and imitation leather.

Figs. 4, 10 and 11 are diagrams showing the internal arrangement of various recent vehicles.

In Turkey and Mozambique the seats can be converted into beds (berths).

In Italy, Turkey, Portugal, Greece and Sweden antimacassars are used; these are attached by round-headed tacks in Italy, buttons in Turkey, press-studs in Greece, and buttons or ties in Sweden.

2. *Floor and wall coverings.*

For the materials used see Table III.

3. *Layout of the compartments, seats, doors, etc.*

Figs. 3, 4, 6, 8, 10 and 11 show the arrangement of the seats and compartments of several recent vehicles.

Sliding doors are generally provided for the compartments. Those of the lavatories, corridors and outer doors are hinged.

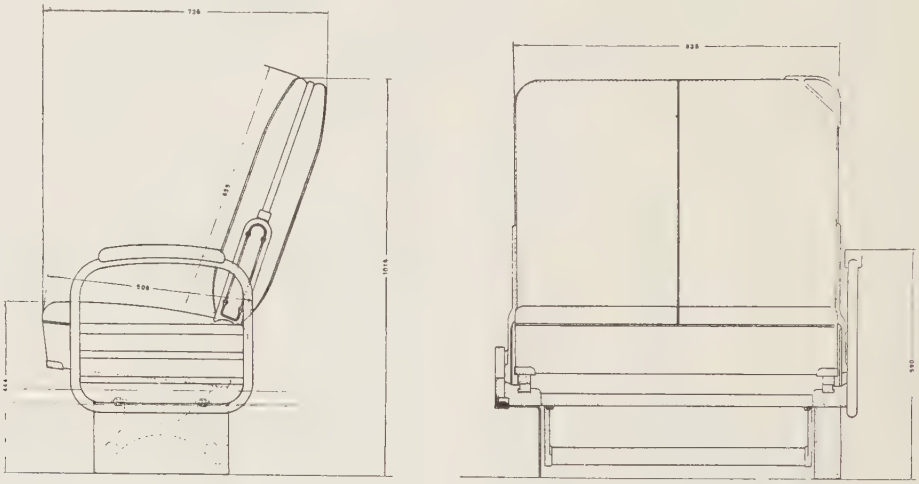


Fig. 5. — Reversible seat of the Portuguese coaches built in America on the « Budd » system.

On railcars and rail motor coaches, folding doors are sometimes used, worked by compressed air (Fig. 11).

The seats are nearly always arranged facing each other, except in Portugal where there are some coaches with all the seats facing in the same direction, and sometimes reversible.

Small luggage is nearly always carried on racks above the seats. However on the rail motor coaches and railcars, there is usually a special compartment for luggage of large size.

In Mozambique the luggage is also stacked on racks in the corridors. On the Italian rail motor coaches there is space for luggage under the seats.

Only in Turkey are there special compartments reserved for women and children on the long distance express trains.

All the Administrations provide various fittings in the compartments for the convenience of passengers (coat-hooks, blinds, mirrors, shelves, ashtrays, photographs). The Swedish private Railways even provide thermometers, water jugs and glasses.

4. *Arrangement of the lavatories.*

See Table IV.

E. Stability of running.

(Type of bogies and suspension).

1. *Bogie vehicles.*

There are many different types of bogies in use on the vehicles of the different Administrations in question. Figs. 12, 13, 14, 16 and 17 show various types of bogies used on recent stock.

Fig. 12 shows the type 27 bogies used on the recent coaches of the Italian State Railways, intended to run at speeds of around 120 km/h. (75 m.p.h.).

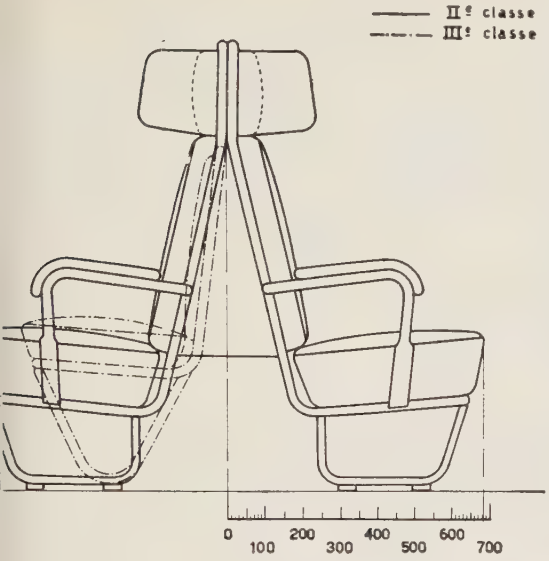


Fig. 6. — Diagram of the seats of recent coaches belonging to the Swedish private Railways.

The total deflection of the springs of a coach carried on two bogies (1) is 5.1 mm/t (0.2 in. per tonne). The deflection of the elastic system of the axle boxes is 1.9 mm/t (0.07 in. per tonne) and that of the bolster 3.2 mm/t (0.13 in. per tonne).

The weight of the suspended part is 35 t for the elastic system of the axle boxes, and 33.5 t for that of the bolster. (2)

Oscillations in the vertical direction are damped out by means of an elastic assembly consisting of coiled springs working in parallel with rubber springs. In the case of the axle boxes the load is distributed in the proportion of 55 % on the steel springs and 45 % on the rubber springs. In the case of the bolsters, the distribution is in the proportion of 75 % and 25 % respectively. The actual damping out of the springs is suitably diminished, owing to the division of the spring into two parts, each consisting of a small number of leaves.

The allowable displacement of the bolster is 34 mm (1.38 in.) on each side. The length of the swing links (vertical) is 410 mm (16.14 in.). Horizontal oscillations are damped out very simply by the friction in the joints of the swing links themselves.

Fig. 13 shows the bogies of the recent rail motor coaches of the Italian State Railways, intended to run at a maximum speed of 140 km/h. (87 m.p.h.).

The deflection of the elastic system is 6.9 mm/t (0.27 in. per tonne) being 2.3 mm/t (0.09 in. per tonne) for the springs (coiled) of the axle boxes and 4.4 mm/t (0.17 in. per tonne) for the

Fig. 7. — Photograph of the seat shown in fig. 6

(1) The deflection of the springs is expressed in millimetre per ton load added on the two bogie vehicle, corresponding to a half ton per bogie.

(2) The weight of the suspended parts relates to a complete two bogie coach.

TABLE III.

ADMINISTRATION (1)	Wall covering	Floor covering
GREECE	Natural wood and plywood	Linoleum and rubber
ITALY	*Coaches :* Linoleum and plastic materials *Rail motor coaches and railcars :* Linoleum and artificial wood (Masonite)	Linoleum and rubber Linoleum and rubber
PORTUGAL	Artificial wood and plastic materials	Linoleum
SPAIN	*3rd class :* Metal sheets *1st and 2nd classes :* Natural wood	*2nd and 3rd classes :* Linoleum *1st class :* Linoleum covered with carpet
MOZAMBIQUE	Natural wood and artificial wood	Linoleum
RUMANIA	Plywood and pergamoid	Linoleum
SWEDEN	Plywood and Masonite	Linoleum
TURKEY	Natural wood	Linoleum

(1) For the names of the Administrations, see Table I.

springs (laminated) of the bolster. The weight of the suspended part is 63 t for the axle boxes and 44 t for the bolsters.

Vertical oscillations are damped out by the friction of the laminated springs, suitably diminished by the division of the springs into small lots of leaves. In the case of the coiled springs of the axle boxes, no special damping out action has been provided, and in practice no tendency to persistent oscillation has been found.

The displacement of the bolster is 35 mm (1.38 in.) on each side. The length of the swing links (vertical) is 310 mm (12.2 in.). Horizontal oscillations are damped out very simply by the friction of the joints.

Fig. 14 shows the bogie of the new articulated rapid electrotrains of the Italian State Railways which run at a maximum speed of 160 km/h. (99 m.p.h.).

The deflection of the elastic system is 8.4 mm/t (0.33 in. per tonne) of which 2.7 mm/t is for the axle boxes and 5.7 mm/t

for the bolsters (1). The weight of the suspended parts is 56 t for the axle boxes and 34 t for the bolsters.

In view of the high speed, vertical oscillations have been damped out rather heavily. For this purpose in the suspension of the axle boxes use has been made of an assembly comprising a laminated spring working in parallel with coiled springs. The distribution of the load between the two types of springs is 50 % on the laminated spring and 50 % on the coiled springs. Laminated springs are used for the bolster, divided up into sets of a few leaves in each case.

The displacement allowed for the bolster is very high (50 mm [1.9 in.] on each side).

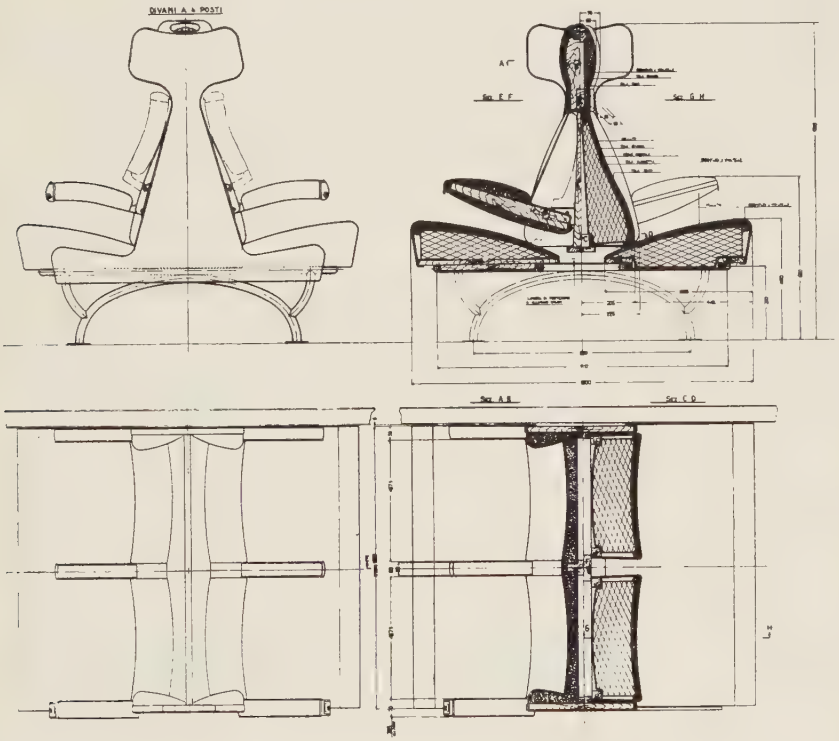


Fig. 8. — Diagram of the standard seat of the recent rail motor coaches and railcars of the Italian State Railways.

The length of the swing links is 500 mm (19.7 in.). They converge together slightly at the top, forming an angle of 6°. The horizontal oscillations are braked by hydraulic shock absorbers with a passage of varying section for the passage of the liquid. The opening is reduced at the end of the travel.

In addition to the centering action of the swing links, the bolster is pushed back

(1) For the sake of uniformity, the deflection is given in millimeters per ton acting on the two bogies, corresponding to half a ton per bogie, although in this case the rake is articulated and consequently there are only two complete bogies per coach. For the same reasons, the weight of the suspended parts considered here is that bearing upon two bogies.

ADMINISTRATION (1)	Wall covering	Floor covering	Capac of the ta
GREECE	Enamelled metal sheeting	Decolite	500
ITALY	Enamelled metal sheeting	Enamelled cast iron plate covered with bronze grille	300
PORTUGAL	Washable paint	Mosaic	250
SPAIN	—	Concrete covered with tiles	400
MOZAMBIQUE	—	—	300
RUMANIA	Painted or lacquer-enamelled sheeting	Reinforced concrete covered with a bronze grille	200 l to
SWEDEN	Masonite painted with white lacquer	Linoleum painted with cellulose or asphalt lacquer	—
TURKEY	Enamelled sheeting	Cement tiles	500

(1) For the names of the Administrations, see Table I.

the water heated?	Differences between 1st, 2nd and 3rd classes	Are there hygienic accessories	Are there urinals?	Products used for cleaning
No	—	Yes	Yes	Potash and phenol
No	None	Yes	No	Soap and hypochloride of soda
in American built stock	None	Yes	No	Potash and Javel water (potassium chloride water)
No	None	Yes	No	—
No	None	Yes	No	Soap and phenol
No	3rd class cast iron pan 1st and 2nd classes earthenware pan	—	Yes	Soap and creoline
—	—	Yes	—	Water and cleaning powders
No	None	No	—	Alysol and Vim

towards the centre by special rubber springs, inside the shock-absorbers. These springs, which act at the end of the stroke, make it possible to run through curves at very high speeds. Fig. 15 shows in diagram form the total centering action on the bolster.

Fig. 9. — Photograph of the seat shown in fig. 8.

Fig. 16 shows the bogie of a recent coach of the Portuguese Railway Co. built by the Schindler Waggon AG, Switzerland. The deflection of the springs is 1.53 mm/t (0.06 in. per tonne) for the axle boxes and 6.37 mm/t (0.25 in. per tonne) for the bolsters. Vertical oscillations are damped out by special hydraulic shock absorbers inside the coiled springs, acting as the guides.

Horizontal oscillations are also damped out by a hydraulic shock absorber. This acts on the bolster through a small rod. The length of the swing links is 265 mm (10.4 in.). They converge towards the top end and form an angle of 16°. The displacement of the bolster is 45 mm (1.8 in.) on each side.

Fig. 22 shows another bogie of the Portuguese Railways, on a recent coach of American construction. This is of the « Pennsylvania » type.

The Rumanian and Turkish Railways

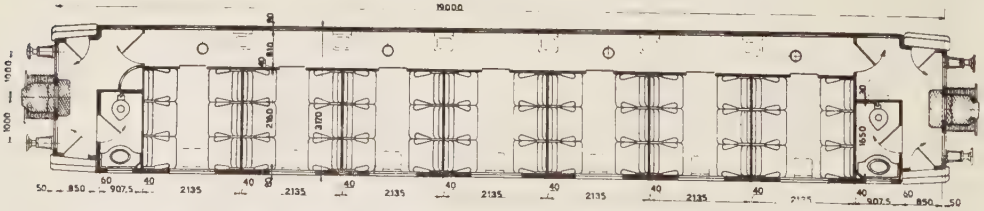


Fig. 10. — Diagram of the interior of a recent 1st class coach belonging to the Portuguese Ry Co.

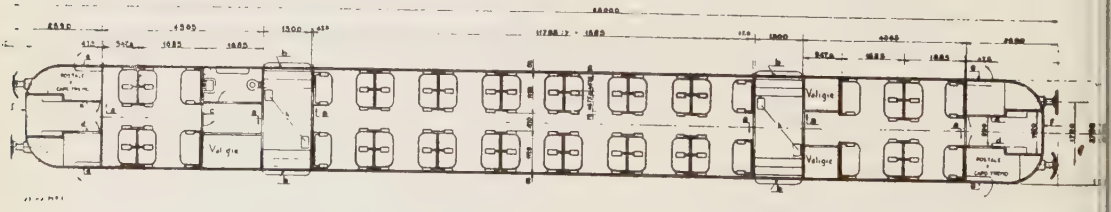


Fig. 11. — Diagram of the interior of a recent rail motor coach of the Italian State Railways.

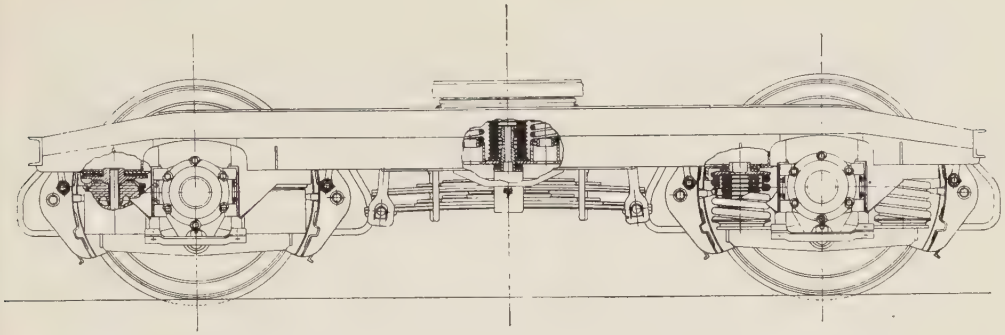


Fig. 12. — Type 27 bogie of the recent coaches of the Italian State Railways (1)

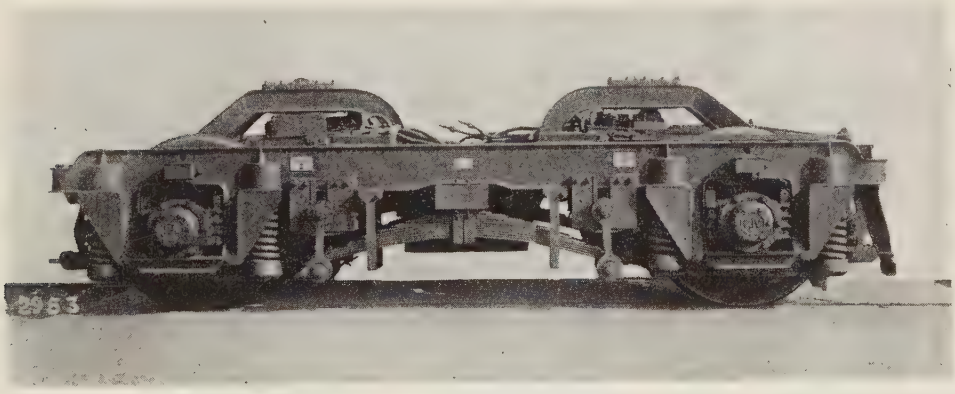


Fig. 13. — Bogie of the recent rail motor coaches of the Italian State Railways.

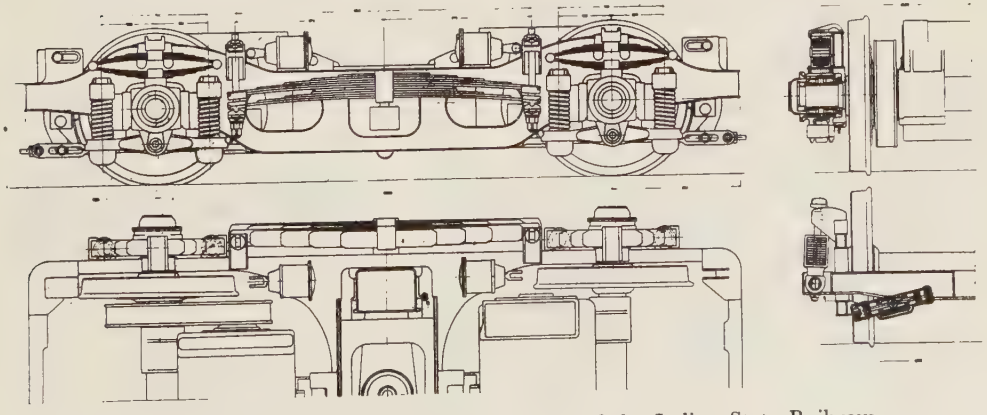


Fig. 14. — Bogie of the new fast electrotrains of the Italian State Railways.

(1) The box on the left on this figure is fitted with a rubber suspension now on trial. This suspension is made of bell-shaped rubber springs. The solution adopted on a large scale is however the one shown on the right.

use « Görlitz » type bogies on up-to-date coaches.

The Spanish Railways use the « Pennsylvania » type bogie. The deflection of the springs is 4.3 mm/t (0.17 in. per tonne), being 1.8 mm/t (0.07 in. per tonne) for the boxes and 2.5 mm/t (0.09 in. per tonne) for the bolsters.

The Swedish private Railways use various types of bogies with coiled and laminated springs together with rubber blocks. Some

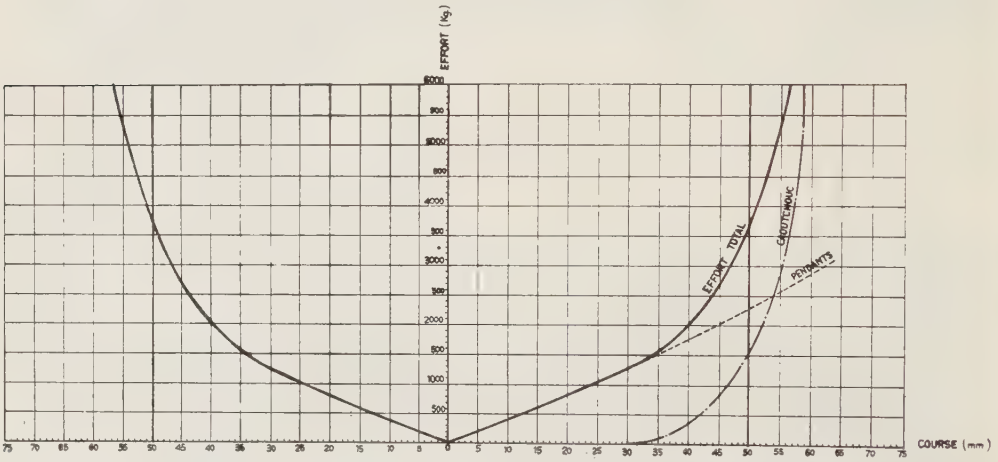


Fig. 15 — Diagram showing the total centering force acting on the bolster of the bogie shown in fig. 14.

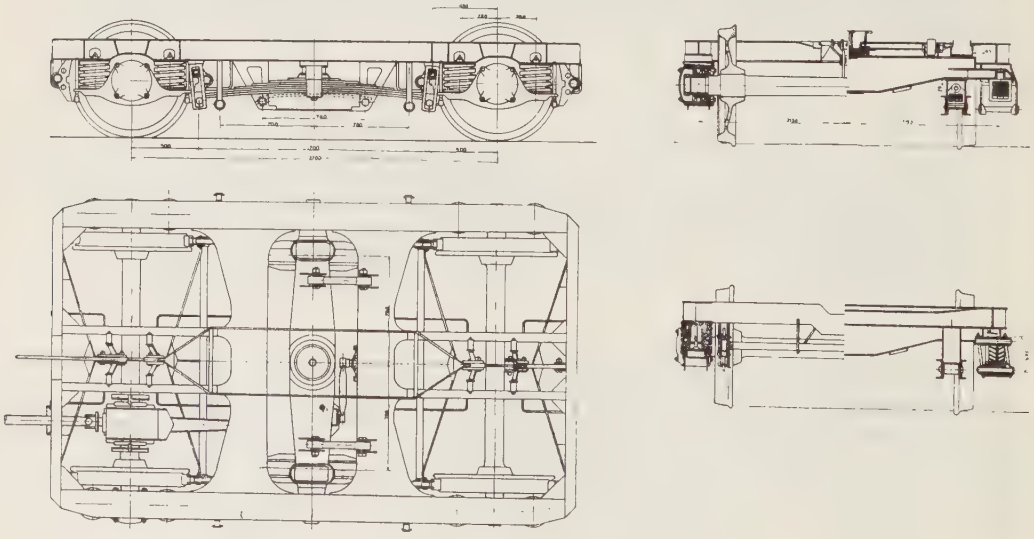


Fig. 16. — Bogie of a recent coach of the Portuguese Railways, made in Switzerland.

types of bogies are fitted with hydraulic shock absorbers.

Nearly all the Administrations in question have bogies with bolsters. Only on some of the railcars of the Rumanian and Italian State Railways are bogies without bolsters used; the results obtained however have not been very satisfactory.

The suspension springs, generally, both coiled and laminated are made of steel. Torsion bars are not used by any of the Administrations in question.

Rubber springs are used in some cases, but only to complete the steel springing (Fig. 1).

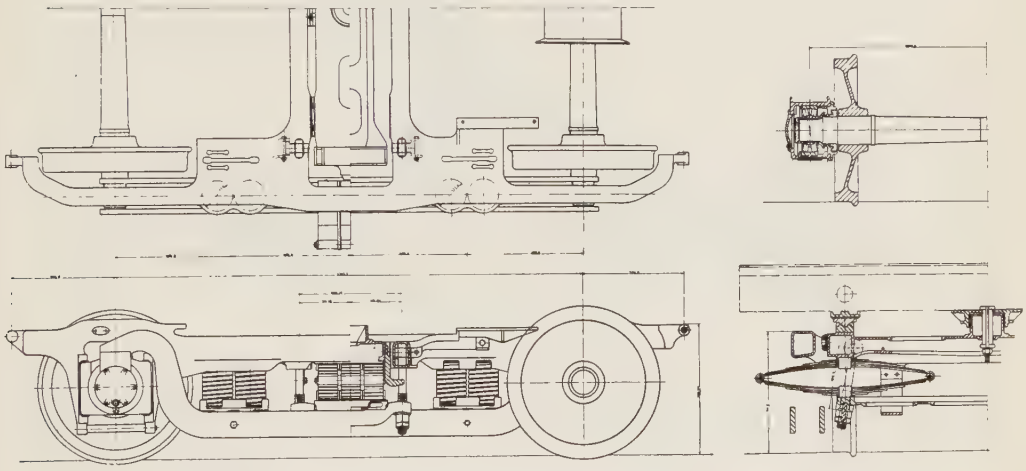


Fig. 17. — Bogie of a recent coach of the Portuguese Railways of American construction.

Rubber springs which play a preponderant part are only used on the bogies of the Italian coaches in conjunction with steel springs, as reported above.

The Administrations did not give any information concerning the kind of steel for the springs nor their heat treatment. On the Italian State Railways manganese-silicon steel is used, water hardened and tempered at 450° ÷ 480° C (1 130° to 1 184° F). For the electrotrains and rail motor coaches on the other hand, a chrome-silicon steel, oil hardened and tempered at 400° ÷ 430° C (1 040° to 1 094° F) is used.

The stresses allowed under the normal static load are 65 kg/mm² (41.27 tons per sq. in.) in the case of manganese-silicon steel and 90 kg/mm² (57.14 tons per sq. in.) for chrome-silicon steel. With coiled springs the stresses do not exceed 30 and 50 kg/mm² (19.05 and 31.75 tons per sq. in.) respectively (in shear).

For the rubber inserts the stress allowed is 18 ÷ 22 kg/cm² (256 to 313 lbs. p. sq. in.) on the Italian State Railways while in the case of rubber springs it must not exceed 6 ÷ 10 kg/cm² (85 to 142 lbs, per sq. in.). The Swedish private Railways agree with the last figure.

No Administration uses wheels with rubber inserts, except the Mozambique Railways which use Michelin pneumatic tyred railcars.

The body is carried on the bogies by the following systems : a central pivot and lateral supports (Italian and Spanish

coaches, Italian electrotrains); central main-casting and side bearers with limited play (Rumanian and Turkish coaches) and finally the method using three points of support — the central main casting which is rigid or nearly rigid with elastic side supports (Italian rail motor coaches).

For stability of running the play in the axle box guides plays a very important part. The play normally allowed is of the

In vehicles of light construction (especially in the case of motor vehicles with heavy equipment in the central portion of the body) there are often movements due to the actual vibration of the body. On the Italian State Railways it was found of great advantage to reduce the friction of the laminated springs of the bolsters, for example by using springs divided up into groups of $6 \div 7$ leaves at the most.

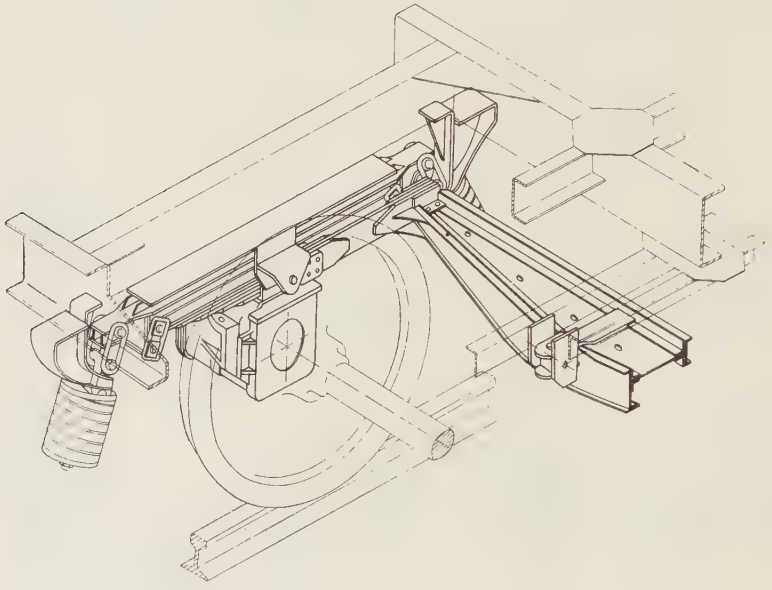


Fig. 18. — Device to guide the axles of the new Italian 4-wheeled coaches.

order of $1 \div 2$ mm (0.039 to 0.079 in.). In order to prevent its formation several Administrations make the sliding surfaces of special materials.

On their electrotrains and the rail motor coaches, the Italian State Railways use heat treated manganese- silicon steel plates sliding on laminated phenoplastic and fabric plates.

The Swedish private Railways use ferro-asbestos or Isolite plates.

None of the Administrations concerned use tyres of special profile.

2. *Four and six wheeled vehicles.*

Nearly all the Administrations who replied use 4 or sometimes 6 wheeled vehicles for stopping and suburban trains.

No special features as regards comfort were reported in connection with these vehicles, except by the Italian State Railways who reported the studies and trials made of a new method intended to facili-

tate the inscription on curves and diminish transversal accelerations.

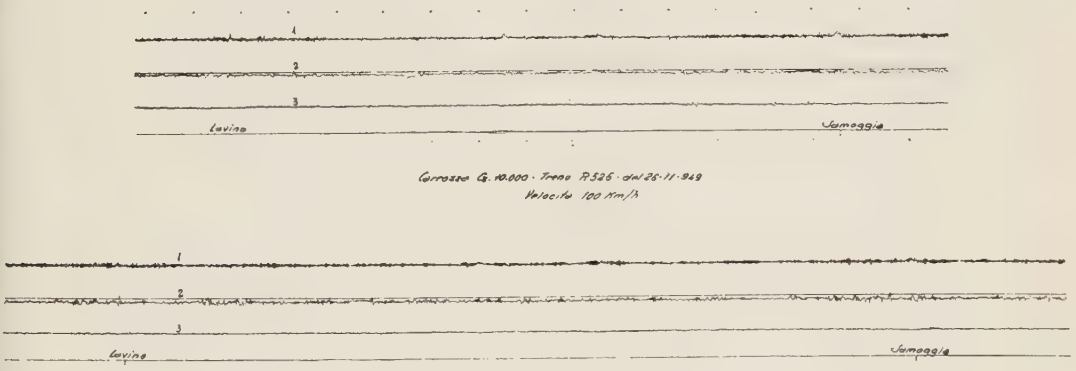
This device shown in Fig. 18 consists of a rectangle the short sides of which are made of special laminated springs while the long sides consist in the one case of a special bolster and in the other of the axle itself. The whole assembly pivots on the middle of the bolster.

mation concerning the measurement of stability of running, measurements which are usually made by means of the classic « Hallade » apparatus.

The Italian State Railways sent in some « Hallade » diagrams which show the high degree of stability of modern vehicles, even those of light construction.

Fig. 19 shows one of these diagrams,

ETR. 209. Train R 521 du 16-11-1949.
Vitesse 155 km/h.



1. *Accélérations verticales.*
2. *Accélérations transversales.*
3. *Accélérations longitudinales.*

Fig. 19. — Running stability measured by means of Hallade apparatus on one of the fast electrotrains of the Italian State Railways running at 155 km/h (96 p. m. h.) (upper diagram) compared with the similar measurements made with the same equipment over the same section of line relating to a heavy coach of the classic type running at 100 km/h (62 m. p. h.) (lower diagram).

This device allows the axle a certain amount of play transversally and, in view of the position of the pivot, it tends to keep the axle in the radial position on curves if the speed of the vehicle is sufficiently high. All this contributes appreciably to a reduction in the transversal accelerations and facilitates inscription on curves for vehicles with a long wheelbase.

3. *Measuring the stability.*

No Administration supplied any information concerning the measurement of stability of running, measurements which are usually made by means of the classic « Hallade » apparatus.

The Italian State Railways sent in some « Hallade » diagrams which show the high degree of stability of modern vehicles, even those of light construction.

Fig. 19 shows one of these diagrams, relating to the recent fast electrotrains of the Italian State Railways (upper diagram) compared with a diagram obtained with the same apparatus over the same section of line relating to a heavy coach of the classic type (lower diagram). It will be seen that in spite of the greater speed (155 km/h. [96 m.p.h.] in the case of the electrotrain compared with 100 km/h. [62 m.p.h.] for the coach), the stability in running of the electrotrain is better than that of the coach.

[624 & 691]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION I.

Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.

REPORT

(Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey and Yugoslavia),

by M. l'Ing. Prof. G. Polsoni,

Inspecteur en Chef Supérieur au Service des Travaux et des Constructions de la Direction Générale des Chemins de fer de l'Etat italien.

To the questionnaire sent to the Railway Administrations of the countries mentioned above, members of the International Railway Congress Association, only the following sent in detailed replies to parts I and II :

1. *FINLAND :* State Railways.

2. *ITALY :* State Railways (Ferrovie dello Stato).

3. *PORTUGAL :* Portuguese Railway Company (Companhia dos Caminhos de ferro portugueses).

4. *PORTUGAL : Mozambique Colony :* The Management of the Harbours, Railways and Transport Service (Direcçao dos Servicos dos Portos, Caminhos de ferro e Transportes).

5. *SWEDEN :* State Railways.

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PART I.

MODERN TENDENCIES IN THE CONSTRUCTION OF RAILWAY STRUCTURES, ESPECIALLY BRIDGES.

CHAPTER I.

General indications.

Each Administration has its own regulations which serve as a basis in calculating railway bridges. These regulations are often modified, because operating requirements tend to result in ever increasing overloads.

The choice between a metal bridge or one in concrete blocks or natural stone, or made of reinforced concrete depends upon technical and aesthetical considerations.

In the calculations for metal or reinforced concrete railway bridges it is often necessary to take account of phenomena of fatigue (repeated stresses), or in particular in the case of metal structures, of elements non-isotropic (welding runs) or subjected to a system of biaxial or triaxial loading.

Below report the various information received and collected on the subject.

Table 1 sums up all the information regarding the typical train and other stresses taken into account in calculating railway bridges.

As for the factors which influence the choice of metal, masonry, or reinforced concrete, they may be said to be the following : economy, convenience, the site, the strength of the foundation soil, the height of the bridge, and in recent years the availability of materials.

In particular :

— The *Italian State Railways* prefer masonry bridges because they are the most economical and involve less maintenance costs. Metal bridges are always erected in localities where there may be subsidences owing to mining operations.

In making an economic comparison between the different solutions, in the case of metal bridges account is taken of the cost of maintenance, painting, amortization of the capital involved over 50 years (the estimated life of a metal bridge).

— The *Mozambique Railways* prefer reinforced concrete bridges, as this material is readily available on site.

— The *Swedish Railways* take the cost price into account, and this becomes the decisive factor if technical and easthetical considerations are equal. If two solutions are of equal technical value, but one is more pleasing from the aesthetical point of view, the latter is given the preference even if it will cost rather more, not forgetting the maintenance costs. Metal bridges are preferred since it is always possible to strengthen them. No bridges have been built of concrete blocks or natural stone for a long time, as they cost more.

During and after the war, very few railway bridges were built owing to the shortage of materials, which also favoured the construction of reinforced concrete bridges.

From the aesthetical point of view, it must be stated that there is a special art in building bridges which implies a thorough technical knowledge, and it is not always necessary to call in an architect.

Generally, it is advisable to have the collaboration of an architect in the case of bridges in urban centres.

In the case of components of a metal bridge submitted to biaxial or triaxial stresses and to calculate the non-isotropic factors (welding runs) were received the following information :

FINLAND : *State Railways.*

— The stresses due to the loads in different directions are added together; the resulting stresses are taken into account.

ITALY : *State Railways.*

In the case of a biaxial system the ideal stresses are calculated from the formula :

$$r_i = \frac{m-1}{2m}(r_x + r_y) \pm \frac{m+1}{2m}\sqrt{4t^2_{xy} + (r_x - r_y)^2} \leqslant r$$

in which :

t_{xy} = tangential stress;
r_x, r_y = normal stress;
r = working limit.

— The welding runs are calculated according to the general regulations in force.

PORTUGAL : *Portuguese Railway Company.*

— The component is considered under the action of each stress acting separately.

— Welding is not used on metal bridges.

SWEDEN : *State Railways.*

— According to the new regulations being prepared by a Commission of the Swedish Royal Academy of Technical Science, in the calculations biaxial stresses are turned into a uniaxial system. A comparative stress σ_r is determined from the formula :

$$\sigma_r = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2} \leq \sigma_t$$

in which :

σ_x and σ_y = traction or pressure;
τ = shearing action;
σ_t = working limit.

No calculations of triaxial systems have been made.

The above proposal means that in the case of a biaxial system of stresses in a run of welding, the comparative stress has to be calculated from the formula :

$$\sigma_r = \sqrt{\left(\frac{\sigma\perp}{\alpha}\right)^2 + \sigma_{\parallel}^2 - \frac{\sigma\perp}{\alpha} \perp \cdot \sigma_{\parallel} + 3\tau^2} \leq \sigma_t$$

in which :

$\sigma\perp$ = traction or pressure perpendicular to the longitudinal direction of the welding run;

$\sigma^{\parallel}$ = traction or pressure parallel to the longitudinal direction of the welding run.

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CHAPTER II.

Metal railway bridges.

a) Main girders.

Plate-web girder or trellis girder.— Design of trellis girders.— Double track bridges.— Use of electric welding.— Other designs apart from simple or continuous girders.— Kinds of steel used.— Railway bridges made of light metals.— Railway bridges of the so-called « composite » type (concrete road and metal main girders).— Special expansion devices for rails on bridges.

FINLAND : *State Railways.*

— Metal bridges preferred up to L = 30 m span with plate-web girder. Height H = 1 10 L.

— The parallel trellis (parallelfachwerkträger) form is preferred in the case of trellis girders because it is simpler and more practical.

— In the case of double track lines two separate bridges are always built, since the second track is usually added at a later date.

— Electric welding has been used in the construction of plate-web girders. After the war 40 bridges were built, 7 to 12 m span, and over a period of two years, no defects have been noted.

— When trellis girders are used for the main girder, the electric welding and adjustment is done in the shops.

— Welding on assembly is not permitted; only for repairing bridges damaged during the war, partial welding was allowed in the case of small runs.

— The span, height, and aesthetical considerations determine the choice of other than simple or continuous girders.

— Recent constructions : the Heinola Bridge (a box beam) with two articulations : 70 m span, 14 m high.

— The kinds of steel used are : St. 37.12 and St. 37.21, and recently St. 44.12 and 44.21 (English steel). No special steels have been used.

— A « composite » type of railway bridge has been built in which the road is made of reinforced concrete slabs. The mains girders are 2 m high, and are spaced 240 cm apart. The slabs are 25 cm thick. The two parts are connected at the top of the girders, which are embedded in the slabs.

— When the span exceeds 20 m balanced supports, are used, and after 70 m rollers.

— In the case of large metal bridges of more than 125 m span and on continuous girder bridges, the rails are joined together on a slant of 1 : 40 over 224 cm. The model

is normal and carried out at the ends of the bridge.

ITALY : *State Railways.*

— Generally for spans of 5 of 18 m twin girder bridges are built. For spans between 18 and 25 m, plate-web main girders; for spans of more than 25 m trellis main girders. These solutions have been adopted for practical and economic reasons.

— Plate-web main girders are advantageous up to a span of 25 m and up to a height of 3 m respectively. The height is limited by the question of transport to the assembling site.

— In the case of trellis girders, preference is given to the form with triangular spaces because these are isostatic. An attempt is being made to eliminate an undue number of rails, which alter the results of the calculations.

— Double track bridges are preferred on double track lines as being more economical. Their weight is equivalent to 9/10ths of the weight of 2 single track bridges.

— In the case of metal railway bridges and for making plate web girders, electric welding has not been adopted. Experiments have been made with electric welding on two plate-web girder metal bridges (over the Topino and the Galdagnola on the Orte-Falconara line) which were welded during assembly. This way of proceeding was exceptional as it is considered preferable to weld in the shops. The maximum thickness welded easily was 50 mm.

— Rivetted bridges are preferred as economy and convenience make it necessary to use Aq 50 steel which is not suitable for welding.

— Apart from simple or continuous girders, we have the old metal arched bridge over the Adda near Paderno, but at the present time bridges are always made with rectilinear bays as these are easily replaced without interrupting the traffic.

— In conjunction with our ferry-boats, we have a three track mobile bridge of articulated assembly, so that it can be adjusted to the inclination of the ship, especially when the liveload is excentric. The steel used on metal bridges is mild or semi-mild or cast.

— The so-called « composite » type of bridge has never been adopted on account of its weight. Roller supports if the span exceeds 12 m. If the span exceeds 60 m a special expansion device is being considered to take up the expansion of the rails.

PORTUGAL : *Portuguese Railway Company.*

— Up to 25 m span and 2 m height the plate-web girder is preferred because it is more economical and quicker to build.

— In the case of trellis girders, the Pratt system is preferred because the diagonals (longer pieces) are under stress as regards the tension, in the case of the main stresses.

— For double track lines the solution preferred, which is the most economical, is a double track bridge. In the case of skew bridges, the solution depends on the skew angle.

— In the case of metal bridges, electric welding has not been used.

— Adoption of simple or continuous girders. Only the Maria Pia Bridge built in 1887 consists of a large arch of 160 m span.

— The steel used for metal bridges is Aq 37 or Aq 40.

— Roller supports and swivels are used if the span exceeds 15 m.

There is a special expansion device for the rails in the case of long bridges (more than 200 m).

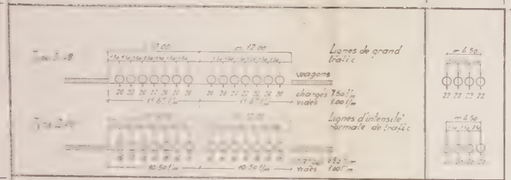
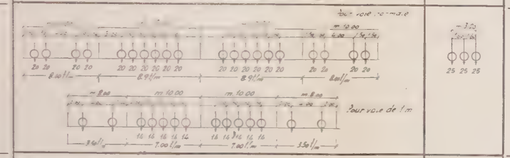
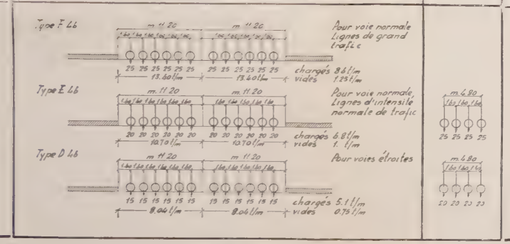
SWEDEN : *State Railways.*

— For spans up to 30 m plate-web girders are preferred because this method of construction does not occasion important secondary stresses as in the case of trellis girders.

— Trellis girders of constant height are preferred, as being simpler and more economic than parabolic members.

— In the case of double track bridges,

TABEL I.

Country	Type train	Isolated overloads	Distributed overloads	Dynamic stresses: Coefficient of increase — Metal bridges	Dynamic stresses: Coefficient of increase — Reinforced concrete bridges	Dynamic stresses: Lateral stress	Dynamic stresses: Centrifugal force $Fc = \frac{P \cdot V^2}{127 R}$	Braking effect	Expansion of reinforced concrete bridges	Contraction of reinforced concrete bridges	Variations in temperature: Metal bridges	Variations in temperature: Reinforced concrete bridges	Wind loading: Loaded bridge	Wind loading: Empty bridge	Repeated stresses: Metal bridges	Repeated stresses: Reinforced concrete bridge	Regulations: Name and date of issue	Regulations: Notes
Finland			—	L = span in metres $\varphi = 1.10 + \frac{31}{30+L}$ If the ballast has a minimum thickness of 40 cm. $\varphi = 1.05 + \frac{18}{30+L}$	V = speed in km/h	5 tons	P = surcharge Without dynamic increase.	$\frac{1}{7}$ of the weight of the train.	—	—	∓ 35° C Unequal heating 15° C		125 kg/m²	175 kg/m²	—	—	26-2-1948	New general regulations are being prepared. The type train will not be changed.
Italy			Allowed.	$\varphi = 1 + \frac{1}{100} \cdot \frac{1400+10L}{20+L} \cdot \frac{50+V}{150}$ If L < 20 m and there are no rail joints. $\varphi = 1 + \frac{40}{100} \cdot \frac{50+V}{150}$ normal thickness of ballast. $\varphi_1 = \varphi - 0.10$	French coefficient of increase. $\varphi = 1 + \frac{0.4}{1+0.2L} + \frac{0.6}{1+4\frac{P}{S}}$ P = permanent load. S = overload.	$E_1 = \frac{P}{100} - 25 \frac{50+V}{150}$ P = weight of the heaviest axle load.	Centre of gravity 2 m above rail level. $Fc = \frac{p}{8}$ p = distributed overload. Without dynamic increase. Not together.	$\frac{1}{6}$ on the open road. $\frac{1}{5}$ near stations.	—	Equivalent to a fall in temperature from 20° C to 10° C if the percentage of reinforcement 1 % to 2 %.	∓ 30°	In current practice ∓ 20° C	h = 3.00 0.50 on the deck 150 kg/m²	250 kg/m²	Acting partly as deflection and partly as tension loading. $\sigma_a = \left(1-0.30\frac{A}{B}\right)\sigma_{Kl}$ (A) < (B) A = (minimum loading). B = (maximum loading). σ_K = allowable loading.	—	New overloads for the calculation of metal bridges. Circular n° 54 of 15-7-45.	The overloads adopted after the war are heavier than those actually occuring and will remain in force for a long time.
Portugal			Allowed.	$\varphi = 1.20 + \frac{17}{28+L}$ $\varphi = 1.19 + \frac{21}{46+L}$ $\varphi = 1.11 + \frac{56}{144+L}$ for L > 150 m $\varphi = 0.30$; according to the way the rails are laid.	—	5 tons Metre gauge track : $\frac{1}{5}$ th of heaviest axle load.	Centre of gravity 1.80 m above rail level. Not together.	$\frac{1}{7}$ on the deck.	—	—	from — 25° C to + 35° C	—	Pression: 150 kg/m² h = 3.00 0.50 on the deck h = 2.50 0.30 1 m gauge	250 kg/m²	$R_1 = \left(1 - \frac{1}{4}\frac{B}{A}\right) R$ if A > B $R_2 = \left(1 - \frac{1}{3}\frac{A}{B}\right) R$ if A < B $R_{1,2} = \frac{1}{24} R$ if A = B A = maximum tension loading. B = max. compression loading. R = maximum loading normally allowed.	—	Regulation for metal bridges 10-41929. Modified in 1933.	It will be necessary to modify the overloads as the locomotive weights have a tendency to increase.
Portuguese Colonies of Mozambique		—	—	main girders $\begin{cases} L \leq 10\text{ m } \varphi = 1.55 \\ L > 10\text{ m } \varphi = 1.20 \end{cases}$ arcs $\begin{cases} L \leq 50\text{ m } \varphi = 1.20 \\ L > 50\text{ m } \varphi = 1.10 \end{cases}$ arches $\varphi = 1.10$ reduced according to the thickness of the ballast.	According to the German standards.	$\left(\frac{1}{5}\right.$ th of heaviest axle load.$\left.\right)$ 4 tons	Centre of gravity 1.80 m above rail level. Not together.	$\frac{1}{7}$ on the deck.	—	Equivalent to a fall in temperature of 15° C if the percentage of reinforcement < 0.5% — 20°C.	from — 25° C to + 35° C	∓ 15° C	h = 2.50 0.30 150 kg/m²	250 kg/m²	—	—	—	The overloads tend to increase but will remain in force for a long time.
Sweden			Allowed.	$\varphi = 1 + \frac{1}{100} \cdot \frac{2200+11L}{25+L} = 1 + \frac{\varepsilon}{100}$ for rails without joints $\varphi_1 = 1 + 0.9 \frac{\varepsilon}{100}$	Where the ballast is 0.4 to 0.6 m thick $\varepsilon_1 = 0.9\ \varepsilon$ Where the thickness is $h > 0.60$ m $\varepsilon_2 = \frac{6-h}{6} \varepsilon$	6 tons Not together.	Centre of gravity 2 m above rail level.	$\frac{1}{7}$ With dynamic increase.	—	Specific contraction of 0.10 to 0.15 per thousand.	∓ 20° C	∓ 15° C	100-150 kg/m² h = 4.00 Standard gauge 100 kg/m² h = 2.80 Narrow gauge.	—	Reduced by 100 kg/cm² of the admissible stress. New regulations are being prepared.	of the admissable stress in steel.	Statliga belastningsbestämmelser av år 1946 for bigvaerk. 1946	These regulations have not yet received official sanction. It is expected that they will remain in force for a long time.

Explanation the French terms :

Lignes de grand trafic = Lines with heavy traffic. — Wagons = Wagons. — Chargés = Loaded. — Vides = Empty. — Lignes d'intensité normale de trafic = Lines with normal traffic. — Pour voie normale = For standard gauge lines. Pour voie de 1 m = For metre gauge lines. — Pour voie normale lignes de grand trafic = Standard gauge lines with heavy traffic. — Charges = Loaded. — Pour voie normale lignes d'intensité normale de trafic = Standard gauge lines with normal traffic. — Pour voies etroites = For narrow gauge lines.

two separate bridges are preferred especially when they are on a skew. Making a fairly accurate calculation of a double track bridge with two or three main girders is a waste of time. The components of a three girder bridge are difficult to make.

— Welding on assembly is permitted, but avoided if possible. Electric welding is used to make plate-web girders. Gas welding is not used. In the last ten years I section plate-web girders have usually been welded. The section of the plates used to make the girders is shown in the drawing (fig. 1).

Fig. 1.

— Maximum thickness welded : 50 mm. The technical regulations specify :

— Plate :

in steel A. 37 and A. 44, maximum thickness 70 mm (the materials are heat treated if the thickness exceeds 50 mm) ;

in steel A. 48 and A. 52, maximum thickness 50 mm (to be heat treated if the thickness exceeds 30 mm).

— Grooved plates :—

in steel A. 48 and A. 52, maximum thickness 65 mm (to be heat treated if the thickness exceeds 50 mm).

— So far electric welding has not been used for trellis main girders. A trellis bridge built in 1945 was made up of I and U sections welded together; the joints however were rivetted.

— The double articulated supported beam bridges are used for spans of 25 to 40 m as this method reduces the height of the girder by nearly one half. Rigid arches are used if the span exceeds 40 m on account of easier machining in the shops, and easier assembly and maintenance. Bridges with flexible arches (Langer system) are counted amongst these.

Recent constructions :

Double articulation supported beam bridge : over bridge in the south of Sweden : theoretical span 27.5 m.

Flexible arch bridges : two bridges over rivers in the north of Sweden : 1) upper bridge, theoretical span : 61 m; 2) lower bridge, theoretical span : 34.40 m.

— Kinds of steel generally used : R = 37 or R = 44 kg/mm^2.

— No so-called « composite » types of bridges have been built.

— When the road consists of concrete laid directly on the main girders, the latter are calculated for the whole load. If needs be, the stresses of the concrete are also checked for the connection between metal and concrete. The diagram shows the way the parts are bound together (fig. 2).

Fig. 2.

— Roller supports are used if the span exceeds 12 m. One or two rollers are used. The bearing load is always centred.

— In the case of metal bridges a special expansion device for the rails is provided (fig. 3).

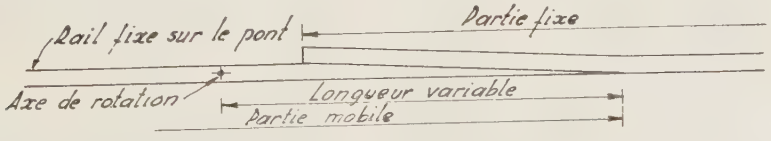


Fig. 3.

Explanation of French terms :

Rail fixe sur le pont = Rail fastened to the bridge. — Partie fixe = Fixed part. — Axe de rotation = Axis of rotation — Longueur variable = Variable length. — Partie mobile = Moveable part.

b) Completely metal bridges.

Laying the track on metal bridges.— Use of electric welding to assemble the longitudinals to the cross stays and the latter to the main girders.— Longitudinal-cross stay fastenings.— Completely welded assembly of cross stays and main girders.— Passing from the permanent way to the metal bridge.— Real and theoretical dynamic stresses in the longitudinals and cross stays.

FINLAND : *State Railways.*

— The track is laid on sleepers as this gives better lateral stability and repairs are easier.

— The longitudinals are generally attached to the cross stays by encasing them in the cross stays so that the edges come in line.

— The passage from the permanent way to the metal bridges is by means of sleepers; the third sleeper is attached to the longitudinals. If the bridge is a very skew one, one end of the sleeper rests on the bridge, and the other on the abutment.

— Check rails are provided if the total length of the bridge exceeds 25 m.

ITALY : *State Railways.*

— Generally it is preferred to lay the track on sleepers. If space is lacking vertically, longitudinal supports are used. Sleepers ensure the maintenance of the gauge and eliminate the risk of derailment which occurs with longitudinal supports in the case of fire.

— The longitudinals are attached to the cross stays and the latter on the main girders by rivetting.

— Rivetted longitudinals are preferred encased in the cross stays. Very rarely, as in the case of the bridge over the Ticino near Sesto Calende, the longitudinals are laid on T irons rivetted to the cross stays.

— Check rails are not used on metal bridges.

PORTUGAL : *Portuguese Railway Company.*

— In wholly metal bridges, the rails are always laid on sleepers.

— Rivetting alone is used in the assembly. The longitudinals are encased in the cross stays.

— The passage from the permanent way to the bridge is generally obtained by fastening the last sleeper to the bond stones (garde grève) and the first sleeper on the bridge to the longitudinals or their extension. In the case of skew bridges, the sleepers are normally fastened to the permanent way (if the skew is small) or the two last sleepers are fixed according to the skew and the others in line with the track (if there is a large amount of skew).

— The joints have only been welded on long bridges to reduce the dynamic stresses. Maximum length welded : 300 m.

SWEDEN : *State Railways.*

— Sleepers are always used for laying the track on metal bridges because this makes maintenance simpler and easier.

— Electric welding has been successfully used to attach the longitudinals to the cross stays and the latter to the main girders.

— According to the space available the fastening, longitudinal-cross-stay, rivetted or welded, has been carried out with a continuous longitudinal or encased on the cross stays.

— Rail joints on metal bridges are to be avoided. On a few bridges the rails have been welded to diminish the dynamic stresses. Maximum length welded : 180 m.

— Checkrails are always used on bridges of more than 10 m span. It is considered that the safety of the traffic is increased thereby.

c) Concrete bridges.

Reinforced concrete slabs in the construction of metal railway bridges.— Passage from the permanent way to the bridge.—

Thickness, kind and size of the ballast.— Waterlight and protective covering.— Separate slabs or in contact with the main girders.— Use of checkrails.— Rail joints.— Rails fixed directly on the concrete.

FINLAND : *State Railways.*

— A watertight bridge is useful for example in the case of an over bridge, but this type of bridge being very heavy is not economical.

— The minimum thickness of ballast in gravel or broken stone is 40 cm below the foot of the rail.

— A watertight covering is provided : double cotton or jute cloth impregnated with bitumen 1 cm thick. A protective layer of reinforced concrete 1 : 3, 4 cm thick with light reinforcements in cross shaped.

ITALY : *State Railways.*

— For reasons of economy concreted decks are not built on metal railway bridges.

PORTUGAL : *Portuguese Railway Co. Mozambique Colony — Ports and Railways.*

— Concreted bridges are not used.

SWEDEN : *State Railways.*

— For some dozen years reinforced concrete slabs have been provided on bridges of a few metres span. A metal 5 span bridge, each span being 12 m built in 1946, was fitted with a reinforced concrete deck. This type of bridge has the advantage of not having any break in the ballast, but it is not economical on average sized or large bridges.

— The track runs onto the bridge without any special device apart from checkrails.

— Normal thickness of the ballast : 60 cm (exceptionally on secondary lines 40 cm). Ballast is generally natural gravel or macadam.

— The watertight covering consists of two layers of bitumenised cotton and three coats of bitumen; the protective layer of concrete is 5 cm thick. Protective coverings are necessary to prevent the water reaching the lower surface.

— Rail joints are eliminated.

d) General comments.

— As regards metal bridges, *the Finnish Railways* have an interesting example of a combined railway and road bridge : the railway above and the road below : the spans are 16.50 m - 16.50 m - 35.52 m - 35.52 m — continuous girder : metres (70.56 - 71.04 - 70.56) — 35.52 m - 16.50 m - 16.50 m; height of the trellis construction : 6.70 m; span of the cross stays : 6.70 m; jutting out footbridge on each side : 2.25 m.

In general the *Swedish Railways* endeavour to simplify the construction and maintenance of metal railway bridges. « Massive » structures (rigid arches) are preferred and the use of electric welding. To simplify maintenance of the track, the depth of ballast on metal bridges must be considered. The development of the use of aluminium for bridges is being followed with the greatest interest. The use of special steels is expected in the case of large metal bridges.

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CHAPTER III.

Massive masonry, concrete, natural stone or ashlar railway bridges.

Recent constructions.— Use of empirical formulae for the dimensions.— Typical structures.— Arches.— Articulated arches.— Making the arches.— Choice between concrete or masonry.— Outer faces.— Expansion and contraction.— Cement content, consistency and granulation of the concrete.— Masonry of natural stone.— Artificial quoins.— Watertight and protective coverings.— Drainage pipes and minimum slope for the coverings.— Expanding cements.— Double track brid-

ges.— Dynamic stresses in massive arches.— Check rails.— General comments.

FINLAND : *State Railways.*

— No interesting masonry bridges have been built since the war.

— No empirical formulae are used to determine the dimensions.

— It is impossible to decide after what size it is advantageous to reduce the thickness of the masonry arches.

— When a masonry arch is calculated as articulated, the articulations are carried out in practice. A bridge with three articulations of 70 m span has been built.

— Generally, natural stone is preferred because it is aesthetically more effective.

— When concrete bridges are covered with ashlar, there has never been any trouble about the joints. In the calculations the variation in temperature is from + 20° C. maximum to — 30° C. minimum, and the contraction of the concrete is taken as corresponding to a fall in temperature of 15° C. Natural stone masonry is divided into two categories, rough work (trowel pointed) and average work (line pointed).

— Sometimes masonry with artificial arch stones has been used.

— The arches are fitted with watertight and protective coverings on the outside. The former consists of double cotton or jute cloth impregnated with bitumen; thickness of the covering 1 cm. The protective covering consists of 1 : 3 concrete 4 cm thick.

— Gravel is used for filling in between the spandrels.

— The drain pipes are taken through the arches and have a minimum diameter of 15 cm; the minimum slope for the protective covering is 1 in 60.

— Difficulty is caused by frost.

— When the two halves of a double track bridge are built in two stages, they are connected together.

— In the calculations for massive arches, if the thickness of the filling exceeds 6 m, dynamic stresses are taken into account.

— On large main line bridges, check rails are used as a precaution against derailment.

ITALY : *State Railways.*

— Recent important concrete railway bridges are : over the Po near Moncalieri, over the Po at Valenza, over the Ticino at Pavia, over the Brenta near Fontanive, over the Oglio at Calcio, over the Piave at Susegana, and over the Avisio near Lavis.

— It is advantageous to reduce the thickness of masonry arches in the case of round or flattened arches to 1/3rd when the span is long.

— In the case of arches calculated as articulated, today only semi-articulated arches are built. The methods of articulation employed are : articulated joint, steel hinged joint, lead pad, and Mesnager type joint (formed of small steel bars embedded in the concrete).

— The arches are built to their full thickness. In the case of brick arches of great thickness, the work is done in several layers and several circular lightening openings of full width are allowed (« Séjourné » method).

— Concrete blocks are preferred for economy and for the rapid execution of the work. Generally the visible parts of concrete arches are simply pointed. On important railway bridges for aesthetical reasons the surfaces are covered with a 3 to 4 cm thick layer of very strong mortar made up of cement and stone detritus. This layer is treated like natural stone. In bridges where only the arches are made of concrete, the visible parts of the fillets are faced. The inside surface is never faced.

— For the expansion and contraction of the concrete a coefficient of elasticity :

$$E = 100\,000 \text{ kg/cm}^2$$

is allowed.

— The mix is :

a) for the arch : 300-350 kg of cement per m^3 of aggregate of suitable granulation;

b) for the spandrels : 300 kg of cement per m^3 of aggregate of suitable granulation;

c) for the filling : 250 kg of cement per m^3 of aggregate.

— Large arches in reinforced concrete are with advantage vibrated by the per-vibration process.

— Natural stone is classified according to its quality :

a) dressed stone for the outer covering;

b) ordinary masonry with levelling courses in dressed stone or brick (2 rows).

According to the way the surface is finished :

smooth dressed stone with the front open;

rough mosaic;

natural stones laid horizontally;

with irregular joints.

Thickness of joints in visible parts : 1 cm.

— Natural stone is not used for the arches.

— The masonry using either artificial or natural stone is only used for the plinths, cornices and top parapets of bridges.

— Watertight coverings in concrete or asphalt are provided when poor quality concrete is used to fill in between the spandrels. There is generally a protective covering of sand 10 cm thick.

— The drainage pipes are taken through the arches near the flank.

Maximum slope of the protective covering	3 in 11
Minimum slope in the case of flattened arches	13 %
Diameter of the drainage pipes .	10 cm
Maximum distance between pipes.	30 m

Frost never causes any trouble.

— The two halves of a double track bridge built in two stages for constructional reasons are kept separated.

In the case of the longitudinal joint, a cover-joint is laid, or cement mortar poured over it.

— Dynamic stresses are not taken into account in calculating massive arches.

— Checkrails or other precautions against derailment are not used because the track is laid in the usual way on bridges.

— In general, massive construction is preferred, and particularly for railway bridges on lines along the coast. Metal bridges are not an economical proposition on account of the high cost of iron and heavy maintenance costs.

PORTUGAL : *Portuguese Railway Company.*

— During the last few years several metal bridges have been replaced by stone bridges.

Recent examples are the Coa, Pala, Quebradas, Tâmega, Quinto Nova, and Mouratos bridges.

— Generally Séjourné's empirical formulae are used for the dimensions up to 8 m span.

— It is advantageous to reduce the thickness of masonry arches if the span exceeds 40 m.

— Masonry arches are not calculated as being articulated, and no articulations are used. The arches are constructed in several layers, taking care to bind them well in.

— Only natural stone is used.

No reinforced concrete bridges have been built.

Natural stone masonry is divided into :

a) dressed stone (used for the visible parts, angles and arches);

b) fretted stone (sometimes used for the visible faces);

c) rough stone (used for the piles, abutments and spandrels).

— The covering generally consists of a layer of cement mortar, a layer of asphalt

and a second layer of a stronger cement mortar, 8 to 10 cm thick. The covering is usually laid over a filling of poor concrete.

— The drain pipes are taken through the arches.

Minimum slope of the covering : 1/20.

Minimum diameter of the pipes : 150 mm.

The distance between the drainage channels depends on the size of the opening, since the pipes are taken near the flanks of the arches.

— The dynamic effects of overloads are not taken into account in the calculations, because masonry bridges are generally built with round arches and full spandrels, the permanent load on which is much greater than the liveload.

— Owing to the very high cost, the extended use of massive construction is not expected.

SWEDEN : *State Railways.*

— No railway bridges of this type have been erected in the last 15 years.

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CHAPTER IV.

Railway bridges in reinforced concrete, pre-stressed concrete, and beams encased in concrete.

a) Future development of reinforced concrete railway bridges.

FINLAND : *State Railways.*

— It is under consideration to replace all bridges up to 8 m span by reinforced concrete bridges with watertight decking.

ITALY : *State Railways.*

— Reinforced concrete railway bridges will be greatly increased as the spans are always becoming larger. From the former spans of 12 m it is now 21 m for ribbed slabs, and 44 m in the case of slabs with continuous ribs.

PORTUGAL : *Portuguese Railway Company.*

— Reinforced concrete railway bridges have only been built up to 8 m span.

PORTUGAL : *Colony of Mozambique — Management of Harbours & Railways.*

— Reinforced concrete is used for all the railway bridges.

SWEDEN : *State Railways.*

— The life of reinforced concrete bridges is not known, but it would appear that they should last as long as metal ones, and the maintenance costs are very similar.

The site is the determining factor when making a decision between metal or reinforced concrete. As the country's output of steel and cement is fairly extensive, reinforced concrete bridges are likely to be developed in Sweden.

b) Pre-stressed concrete railway bridges

Part III deals with the future prospects of pre-stressed concrete.

c) Railway bridges with concrete encased joists.

Drawings-types.— Solid slabs and ribbed slabs.— Maximum span built.— Calculation of these bridges.— Distribution of the overloads over the full width of the slabs.— Minimum distance between 2 adjoining joists.— Transversal reinforcement.— Skew bridges.— Double track bridges.— Arrangement of the joists and the slabs.— Transversal section.— Kerbs.— Thickness of the ballast.— Coverings and drainage.— Rails fastened directly to the joists.— Dynamic stresses.— General comments.

FINLAND : *State Railways.*

— Standard designs up to 5.50 m span. In other cases a special design is got out

each time. The maximum span built to date is 14 m.

— Only the metal takes the load and the overloads are distributed over the 5 m width of the single track bridges and 9 m width of the double track bridges. Minimum distance between the flanges of two adjoining joists is 8 to 10 cm.

— Transversal strengthening is provided in a purely empirical manner both above and below.

— In the case of skew bridges, the joists are laid obliquely and calculated accordingly.

— A single slab is preferred for double track bridges.

— The joists are completely encased in concrete.

— No special supports are provided up to a span of 8 m. On large bridges there is a supporting device for the rails.

— The upper edge of the kerb is usually on a level with the lower side of the sleepers.

— Dressed stone kerbs usually are the most satisfactory.

— Minimum thickness of ballast below the foot of the rail 40 cm.

— Watertight and protective coverings are used. The surface of the concrete is cleaned and then a layer of bitumen applied.

— Slope given to the protective covering to ensure water running off : 1/50; maximum distance between pipes equal to the span. Diameter of the pipes : 15 cm. In calculating these bridges an allowance is made for the dynamic stresses.

— Concrete encased joists are a good method for small bridges but are not economical.

ITALY : *State Railways.*

— Typical designs up to a span L = 18 m. For $L \leqslant 15$ m, standard section joists. For $L > 15$ m, D.I.N. section joists.

— For $L > 18$ m, this type of construction is heavy and consequently uneconomical and of no advantage.

— Maximum span to date 16.75 m on the new bridge crossing the Impero on the line from St. Pierre-d'Arène to the French frontier.

— The additional strength due to the concrete is not taken into account.

— The liveloads are distributed according to the span L :

a) single track bridges :

for $L \leqslant 5$ m : width of slab used : 3 m;

for $5 < L \leqslant 9$ m : width of slab used : 3.50 m;

for $L > 9$ m : width of slab used : 9 m;

b) double track bridges :

width of slab used : 3.50 m (equal to the space between the tracks).

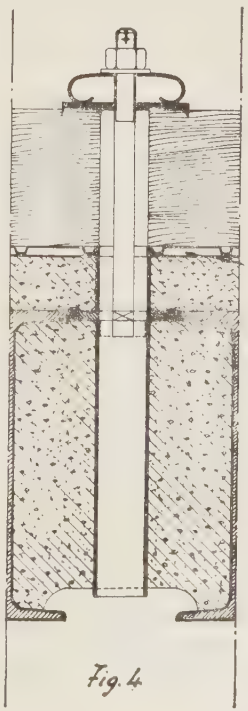

Fig. 4

— Minimum distance between the flanges of two adjoining joists : 10 cm.

— The joists are connected together transversaly by stays in a single row in the case of small joists or else in two rows, when the height is greater. Diameter of the stays : 20 to 25 mm. This method of strengthening a bridge is purely empirical.

— In the case of skew bridges, no reduction in the moments is taken into account. The girders are arranged parallel to the heads and the stays parallel to the masonry of the abutments.

Sometimes in the case of slabs that are very much on the skew, and very wide, the stays are arranged in line with the joists.

— In the case of double track bridges a single slab is generally preferred because the liveload is thereby distributed over a larger surface.

— The lower sides of the joints are left uncovered and painted.

Sometimes the joists are covered with a layer of concrete with 2 to 3 cm reinforcements.

— The slabs rest on the abutments over a reinforced concrete distribution plate to spread the loads. If $L > 10$ m, the bearing on the distribution plate is carried out by means of a rail to ensure that the span shall not be exceeded.

— The top of the kerb is made level with the running surface of the rail.

— Reinforced concrete kerbs in one piece with the slabs are preferred because dressed stone kerbs are liable to break away when trains pass.

— Minimum thickness of ballast : 60 cm (10 cm-layer of sand to protect the watertight coating, and 50 cm of ballast).

— Watertight covering of two 1 cm layers of asphalt with a 10 cm layer of sand on top. The covering follows the line of the kerb which encloses it. Slope of the slab to ensure water draining off : 2 %. The pipes are run near the piers or abutments.

— Sometimes to save space vertically, the rails are fixed directly on the joists by the method shown in the drawing (fig. 4).

— To calculate the dynamic stresses, the French majoration formula is used.

— Railway bridges with the joists encased in concrete are interesting when not much room is available vertically. They are of advantage from the point of view of rapidity of construction, but are not economical in the case of long spans.

SWEDEN : *State Railways.*

— Certain private companies now nationalised built several railway bridges with concrete encased joists. All these bridges are very old ones, however, about 75 years old, originally built as metal bridges, 25 to 35 years ago they were strengthened by encasing them in concrete or reinforced concrete.

— On the smallest bridges, with 4 joists or even more, with a maximum span of about 6.5 m solid slabs have generally been used.

— A bridge with two 13 m girders has been built with ribbed slabs.

— We have not made any such bridges on our Railway.

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CHAPTER V.

Road bridges and over-bridges.

Choice of materials for over bridges.— Standard designs.— Large girders or girders with several spans.— Use of electric welding for metal over bridges.— Over bridges in special steels or light alloys.— Deck of over bridges with metal main girders.— Moveable roller supports.— Supports for the slabs.— Dynamic stresses.— Arrangements to link up the roadway between the bridge and the abutment.— Watertight coverings.— Protective coverings for reinforced concrete slabs.— Methods of fastening the rails on the slabs.— General comments and present tendencies.

FINLAND : *State Railways.*

— Generally reinforced concrete is preferred for such bridges owing to its economy and the lower height of bridge required. Standard designs for 3 span over bridges, the centre span of which bridges is for two lines.

Large span beams are the best.

— The best type of deck is of concrete with a bitumen roadway. When exceeding 20 m span, over bridges with vertical reactions are fitted with moveable roller supports.

— Rectangular slabs of reinforced concrete or joists encased in concrete are fitted with steel plates which rest on rails driven into the abutment.

— The increase to allow for dynamic stresses is 40 cm at most. The rules concerning liveloads are under revision.

— The best arrangement for the joint between the bridge and the abutment is a ribbed plate.

— The watertight covering consists of two layers of cotton or jute fabric impregnated with bitumen, which in turn is protected by a layer of reinforced concrete sometimes used as the wearing surface 4 to 12 cm thick. Generally the wearing surface is made of concrete-asphalt or hard cast asphalt over the protecting concrete.

— Generally these frames or girder bridges have been erected over 2 or 3 lines.

ITALY : *State Railways.*

— A masonry or concrete arch or reinforced concrete beam is preferred as being more economical than a steel structure.

— Standard designs of over bridges up to 15 m span; reinforced concrete slabs are used up to a span of 13.50 m and joists encased in concrete up to a span of 20.50 m.

— For large spans, reinforced concrete arches and parapet-girders deserve consideration.

— In the case of over bridges in stations, large span beams are preferred without intermediate supports which might interfere with taking up the rails at some time. The rigid solid frame type has been adopted with thin reinforced concrete piers.

— Electric welding is used only on secondary work (parapets, etc.).

— The best type of deck is a reinforced concrete slab on transverse metal girders with asphalt paving for the roadway.

— Both metal and reinforced concrete over bridges are equipped with moveable roller supports if the span exceeds 20 m.

— Rectangular reinforced concrete slabs with their limited span do not require any support.

In the case of concrete encased joists the support consists of a rail embedded in the concrete.

— The following formula is used for the dynamic stresses :

$$\varphi = 1 + \frac{20}{40 + L}$$

according to the N/6018 Standards of 9/6/45 of the Ministry of Public Works. These specifications give the liveloads, which must be taken into account in calculating road bridges.

— Generally, there is no joint between the bridge and the abutment. When, however, the bridge is a very large one, such as that over the Po at Mezzanacorti, toothed joints corresponding to the moveable supports have been provided.

— Watertight coverings consisting of 8 to 10 kg of natural bitumen per 100 kg of natural asphalt mastic and 50 kg of sand.

— On over bridges the footpath is covered with asphalt and the roadway paved with small pressed asphalt blocks with cement mortar joints.

— The present tendency is to do away with metal over bridges which are uneconomical from the maintenance point of view, and build reinforced concrete over

bridges with continuous slabs in one piece with the side walls.

PORTUGAL : *Portuguese Railway Company.*

— The designing and building of road bridges and over bridges are carried out by the State (Junta Autonoma dos Estradas). In the case of over bridges in stations, two types are used :

a) long girders without intermediate supports;

b) a girder of several spans.

PORTUGAL : *Mozambique Colony — Management of the Harbours & Railways.*

— Reinforced concrete is preferred for reasons of economy and ease of construction.

— In particular the girder type with several spans is the most economical. Over bridges are equipped with moveable roller supports if the span exceeds 20 m.

— The best supports for reinforced concrete slabs are steel plates.

— The dynamic stresses are taken into account through the dynamic coefficients already mentioned above.

— The best arrangement for the road joint between the bridge and the abutment is in asphalt, with a zinc spring plate (fig. 5).

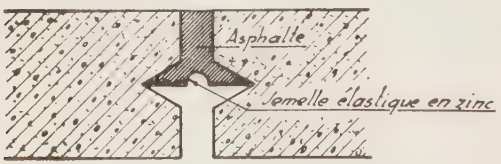

Fig. 5.
Explanation of French terms :
Asphalte = Asphalte. — Semelle élastique en zinc = Elastic plate made of zinc.

— The covering used is in cement mortar with a special ingredient to increase the watertightness, or a layer of asphalt and sand 2 cm thick.

— The road can be made of reinforced concrete slabs or concrete with 250 kg/m² of cement.

— The best way to fix the rails of a tramway or light railway line to the slabs is to use sleepers and macadam.

SWEDEN : *State Railways.*

— Road bridges and over bridges are generally designed and built by the Royal Administration of Bridges and Roads or by the Commune concerned.

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CHAPTER VI.

Piers and abutments.

Present tendencies in the construction of piers.— Massive piers, light piers in reinforced concrete, metal piers.— Separate supports or a supporting bank for concentrated loads.— Abutments with return walls or wings.— Abutments in reinforced concrete.— Transmission of horizontal stresses to the foundations.— Supporting gear attached to the piers.— Abutments and walls in one piece or separate.— General comments.

FINLAND : *State Railways.*

— Natural stone or cased-in concrete piers are preferred with the separate bearing blocks in granite.

— Abutments with solid return walls are preferred because these withstand the thrust of the earth better. The foundation is concentrated in a smaller area.

— The transmission of horizontal stresses to the foundations is permitted. Fixed supports are not usually attached to the piers; if they are, the calculations take the transmission of these stresses into account.

ITALY : *State Railways.*

— The piers are built of concrete blocks or reinforced concrete with supporting banks.

— The choice of abutments with return walls or perpendicular wing walls or flaring wing walls depends upon which solution seems to be the most economical. For flattened arches wing walls are preferred. To clear water courses, the walls are perpendicular on the upstream side and flared out on the downstream side.

In the case of under-bridges the walls are flared out for the benefit of the traffic.

— Reinforced concrete abutments of cellular construction are rarely built; solid abutments are preferred as being stronger.

On an over bridge on the Pisa-Livorno line, the abutments have been made with a cellular structure, but the results were not very satisfactory.

— In the case of masonry bridges, the horizontal stresses are not taken into account in the calculation of the piers. In the case of reinforced concrete bridges with the roadbed in one piece with the abutments and in the case of the piers of metal bridges, the horizontal stresses are allowed as being transmitted to the foundations.

— The supports are attached to the piers.

— Abutments and walls in one piece are preferred as being stronger.

— At the present time there are no special tendencies in the construction of piers and abutments.

PORTUGAL : *Portuguese Railway Company.*

— Massive piers in natural stone are preferred with separate bearing blocks in granite. Abutments with return walls are the most economical.

— Wing walls are used to control the waterways and in towns for under-bridges.

— The whole of the horizontal stresses acting on the bridge can be transmitted to the foundations.

— Frequently the bearings of one span of a bridge are attached to the piers, but those of the next span must be moveable.

— Preference is for abutments with walls in one piece.

PORTUGAL : *Mozambique Colony — Management of Harbours & Railways.*

— In the case of girder bridges, the piers are in cyclopean concrete or natural stone.

— Piers and supporting banks in concrete blocks are preferred owing to the rapidity of construction.

— The preference is for abutments and wing walls or return walls when the subsoil is wet.

— The whole of the horizontal stresses are taken as being transmitted to the foundations.

— Sometimes, the abutments and walls are not in one piece, but are separated by joints.

SWEDEN : *State Railways.*

— Massive piers are no longer built in natural stone or concrete with a protective layer to preserve the concrete from the effects of ice.

The uselessness of such a covering and the difficulty of avoiding cavities behind dressed stones led to this type of construction being given up.

The piers are built either as massive concrete piers with a very strong outer reinforcement in squares, or as thin reinforced concrete piers.

— Metal piers are used with concrete or reinforced concrete supports. The special features of the site determine the choice of the type.

Piers in river beds are generally finished off on the upstream side with rectangular cutwaters with rounded corners to facilitate the floating of the wooden framing. The upstream side generally has a slope of 4/3 to break up any icefloes.

— Supporting banks of reinforced concrete are preferred.

— Return walls are preferred in the case of large abutments. Small abutments have

perpendicular or flared wing walls of a maximum length of 4 m.

— The piers are so calculated that all the horizontal stresses can be transmitted to the foundations. The fixed supports are often sited on the piers in the case of continuous girders with two spans or in the reinforcement of an old bridge with weak abutments.

— The abutments and return walls are preferably separated by joints to avoid cracks.

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CHAPTER VII.

Retaining walls.

Semi-empirical formulae and methods of soil mechanics to determine the thrust of the earth and strength of the foundation soil.

FINLAND : *State Railways.*

— The thrust of the earth and strength of the foundation soil are determined by semi-empirical formulae if the foundation soil is good. If it has to be artificially reinforced, recourse is had to geotechnics.

ITALY : *State Railways.*

— In ordinary cases, the thrust of the earth and the strength of the foundation soil are always determined from standard tables; in exceptional cases, owing to the size of the walls and specific nature of the soil, we make use of the more up to date methods of soil mechanics.

PORTUGAL : *Portuguese Railway Company.*

— Semi-empirical formulae are used.

PORTUGAL : *Mozambique Colony — Management of Harbours & Railways.*

— The thrust of the earth and strength of the foundation soil are always determined by semi-empirical formulae.

SWEDEN : *State Railways.*

— Semi-empirical formulae are used according to the opinions of geotechnical experts. For very large structures, researches and tests according to up-to-date methods are carried out and the samples compared with those of soils about which experimental data are already available. In Sweden as well as in Finland and Norway, it is quite normal to find kinds of soil that are not found in any other countries.

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CHAPTER VIII.

Tunnels.

Protection of reinforced concrete facings against corrosion due to smoke.— Precaution to avoid current losses or short-circuits due to damp on electrified lines.

ITALY : *State Railways.*

— Generally the facings of tunnels are of brick or natural stone masonry. Exceptionally concrete blocks are used in order to reduce the thickness of the masonry when there is a heavy earth thrust. The minimum thickness of the facing is then about 80 cm and consequently corrosion due to smoke is negligeable.

Sometimes, in the case of reinforced concrete tunnels, the thickness of the facing has been increased and good quality concrete with cement with a low lime content has been used and active ventilation by lateral openings has been provided.

— To avoid losses of current or short-circuits on electrified lines owing to damp, the masonry is protected by a cement-gun coating and by drainage, and sometimes by injecting cement or cement mortar behind the facing.

PORTUGAL : *Portuguese Railway Co.*

— Tunnels are constructed of natural stone or brick without any facing.

There are no electrified lines on this railway.

SWEDEN : *State Railways.*

— Concrete facings are not protected in any special way.

— In the case of electrified lines, if cracks allow water to run down the walls, the contact wires are protected by a roofing of concrete or steel plate.

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CHAPTER IX.

Platform roofs.

Material used for platform roofs.— Examples of roofs.— Glazing to link up separate roofs.— Dissymetrical loads and wind loading.

FINLAND : *State Railways.*

— The materials used for roofs are concrete, steel and wood.

The dissymetrical loads allowed for are snow and wind.

ITALY : *State Railways.*

— Nowadays roofs are made of reinforced concrete because such roofs are very economical from the maintenance point of view and pleasing from the aesthetical point of view.

— In the new Rome station, towards the main hall, the roofs are joined by glazed panels.

— The dissymetrical loads allowed for in the calculations are :

a) snow loading : 80 kg/mm²;

b) wind loading : 40 kg/mm² pressure on one side and 40 kg/m² depression on the other side.

PORTUGAL : *Portuguese Railway Co.*

— The materials used are steel, and reinforced concrete, but reinforced concrete is preferred because maintenance is very economical. The only dissymetrical load allowed for in the calculations is wind loading, which is taken as a horizontal load of 150 kg/m².

PORTUGAL : *Mozambique Colony — Management of Harbours and Railways.*

— Generally the roofs are made of metal.

SWEDEN : *State Railways.*

— Wooden roofs are more usual than metal roofs. A trial roof of a very light wooden construction has been carried out.

Roofing : 3 planks of a total thickness of 7.5 cm.

Width : 2 × 3 m = 6 m.

Load tests carried out with a uniform overload of 150 kg/m².

— The investigation into this construction which has revealed very large deformations has not yet been completed.

— The following overloads are allowed for in the calculations for roofs :

a) dissymetrical snow loading : 75-200 kg/m² depending upon the part of Sweden;

b) as regards stability, horizontal wind loading of p = 100 to 125 kg/m² on the vertical projection.

For lifting, a vertical force $\frac{}{2}$ direct from bottom to top on the horizontal projection.

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CHAPTER X.

Testing of bridges.

Testing of bridges and its object.— Instruments to measure static and dynamic stresses due to liveloads.— Instruments to measure the effects of slow acting forces.— Instruments to measure the local stresses in a bridge due to permanent loads.— Special tests on railway bridges.— Value and use of sounding bridges.

FINLAND : *State Railways.*

— Metal railway bridges are tested by running the heaviest stock over them in order to reveal the actual deformations and to compare them with the theoretical

deformations calculated for the same liveload.

— A bridge engineer attached to the General Management is in charge of these tests.

— Static liveload stresses are measured by an extensometer.

— The testing of bridges is considered of great use in determining the frequency of the vibrations.

ITALY : *State Railways.*

— Before the bridge is opened to traffic static and dynamic tests are carried out to control the actual structure compared with the calculated data. In reinforced concrete structures the elastic deformations approach the theoretical ones taking as coefficient of elasticity :

$$E = 35\,000 \text{ kg/cm}^2.$$

— Bridges are tested by officers of the Department or Works Department.

— The instruments used to measure the static effects of the liveloads are :

a) Frigerio, Salmoiraghi, Griot and Mahr flectometers and Huggenberger deflectometers;

b) Mahr, Huggenberger and Withmore extensometers;

c) Salmoiraghi and Galileo clinometers;

d) optical collimators.

— To measure the dynamic effects of the liveloads Stoppani and Rabut flexographs and Salmoiraghi flexometers are used.

— To measure the effects of slow acting stresses the following instruments are used : Mahr and Withmore clinometers; clinometers.

— No instruments are available to measure the existing stresses due to permanent loads.

— Special tests were made before the war to determine the proper vibration frequency of railway bridges by means of a vibrating machine on a wagon, but this was destroyed during the war. It is intended to reconstruct an apparatus to record stresses with a Hathawbay electric extensometer.

— The value and utility of sounding bridges are very great since they make it possible to take the results of trials into account in designing similar bridges.

PORTUGAL : *Portuguese Railway Co.*

— Load tests are made before the bridges are opened to traffic, and afterwards if necessary to check their strength.

The tests consist of measuring the stresses and tension in the lattice girders and components under the action of static and dynamic loads (generally for the heaviest train running on the system). The object of these tests is to check the stresses and deflections obtained by calculation.

— The tests are carried out by the « Estudos » and « Obras Metalicas » Departments.

— The instruments used are : extensometers and flexometers for static tests and mechanically recording flexometers and extensometers of the Rabut and Mannet types for the dynamic tests.

PORTUGAL : *Mozambique Colony — Management of Harbours and Railways.*

— Tests of the load on metal and reinforced concrete bridges are carried out before they are opened to traffic and annually during their life to check the deflections, stresses, and oscillations.

— The « Estudos e Construçâo » and « Service Via e Obras das Divisioes de Exploraçâo » are in charge of these tests.

— The instruments available are recording dynamometers, Cambridge chronometers and vibrations recording equipment for vertical, horizontal and rotational readings.

— A great deal of importance is attached to the usefulness of sounding bridges to

keep a check on them throughout their life.

SWEDEN : *State Railways.*

— Tests are usually made of the loads on large and average sized metal bridges. In the case of small railway bridges, the full range of tests is only carried out when there is any uncertainty about the foundations.

Reinforced concrete bridges are not tested under load.

— Load tests are made before the bridge is opened to traffic. The liveload is obtained by running a train of special tank-wagons.

— The object of these tests is to verify the safety of the construction as well as the degree of agreements between the real stresses and those obtained from the calculations.

— The Bridges and Highways Department is in charge of these tests.

— The static effects of liveloads are measured by extensometers, Huggenberger deformeters and comparators.

— The dynamic effects are measured by means of resistance wire extensometers.

— The effects of the temperature is checked by means of resistance thermometers and thermo-elements.

— The movements of the supports are measured by means of precision level readings.

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PART II.

Results obtained in the construction of reinforced concrete bridges.

a) *The first reinforced concrete bridge constructed on the system and its length.— The oldest reinforced concrete bridge in use.— When did reinforced concrete leave the trial stage?— Characteristics of interesting railway bridges.— Maximum span of a fully rectangular section railway bridge or with T or box beams.— Standard types.— Other systems than the solid or grooved slab;*

b) *steels used.— Welded joints.— Essential conditions for a proper reinforcement.— Use of high tensile steels.— Minimum thickness of the covering.— Concrete used : amount of cement and water, granulation, compactness.— Essential conditions for making good concrete.— Cracks in reinforced concrete.— Vibration.— Materials to increase the workability and compactness.— Ways of protecting reinforced concrete against bad weather.— Cements used;*

c) *methods of calculating reinforced concrete railway bridges.— Allowable stresses.— Addition for dynamic effects.— Transversal distribution of the liveloads over the width of the bridge.— Skew bridges.— Supports.— Articulation.— Prefabricated parts.— Watertight and protective coverings.— Minimum thickness and kind of ballast.— Rails attached directly to the slab.— Damage to reinforced concrete railway bridges.— General comments.*

FINLAND : *State Railways.*

a) The first reinforced concrete railway bridge was built in 1916 and is at the present time the oldest type with a full slab deck in two spans of 8.40 m.

— Reinforced concrete passed the experimental stage in 1920.

— Maximum economic span for a fully rectangular section railway bridge 7 m.

— Standard designs for 1.50 to 11 m spans.

— The condition of the foundations, the span and constructional height determine the choice of systems other than solid or ribbed slab;

b) St. 37 round steel is generally used and the welded joints are allowed with deduction of 20 %. Minimum thickness of the covering : slabs 2 cm, other components 3 cm.

— Amount of cement : 300 to 350 kg/m³.
Water : cement ratio : 0.45-0.60.
Flexibility : 3.5 to 7° VB.

Granulation : the screening percentages as sifted out are added together : □ 0.125; 0.25; 0.50; 1; 2; 4; 8; 16; 32 and 64 mm and this sum gives the screening figure H. H must equal 330-570.
Filler percentage = 2-3.

— Reinforcing and dividing joints are recommended to prevent reinforced concrete from cracking.

— Concrete has been vibrated with good results, with rod vibrators and other processes;

c) admissible stresses :

for the concrete : admissible stress

$$\leqslant \frac{\text{breaking strength}}{2.5} ;$$

for the reinforcement : admissible stress

$$\leqslant \frac{\text{limit of elasticity}}{1.85}$$

— The increase for dynamic effects is :

$$\varphi = 1.05 + \frac{18}{30 + L}$$

— This formula has given good results.

— Transversal width over which the overload is distributed : 5 m.

— For skew bridges the oblique span alone is considered.

— Supports :

up to a span of 8 m; no special supports;
from 8 to 12 m; sliding gear;

L > 12 m : roller supports.

— Different articulations have been used with satisfactory results.

— Watertight and protective coats as in the case of concreted decks.

— Minimum thickness of ballast 40 cm.

— Reinforced concrete railway bridges have given satisfactory results.

— Simple beams in reinforced concrete are generally preferred to rectangular beams for small spans, and the slab type up to 12 m.

— It is considered that the span limit of arches is 100 m in the case of a railway bridge.

ITALY : *State Railways.*

a) The Companies who operated the Italian Railways up to 1905 built a few reinforced concrete bridges, but it is only since 1920 that reinforced concrete has become a standard material. The oldest existing reinforced concrete bridge is the Saint Laurence bridge at Rome built in 1908; three 10 m spans.

Particularly interesting railway bridges are : the bridge over the Orco on the Turin-Milan line : five 24.20 m spans. The structure, of arches flattened, by 1/10, is cellular. The arches are 50 cm thick at the keystone and 80 cm at the springing. The calculations show that the permanent load falls upon the arches and the live-load is divided between the arches and the upper structure; the bridge over the Brenta on the Bassano-Padova line : 5 continuous 16 m spans with four intermediate pillars 12 m high; the bridge over the Ombrone on the Rome-Pisa line : 3 continuous 34-44-34 m spans with hanging supports in reinforced concrete. Height of the piers : 10.50 m; the Recco Viaduct, on the Pisa-Genoa line; the Santo Spirito Viaduct on the Isernia-Sulmona line; the continuous parapet-girder Pedogna bridge on the Lucca-Piazza al Serchio line; the Desenzano Viaduct on the Garde with encased framework.

— Maximum span for a fully rectangular railway bridge 4 m. For larger spans T beams are used.

The maximum span for a T-beam railway bridge is 21 m. For continuous beam bridges the span may be as much as 44 m.

— Some old standard types are available which will be modified if necessary for the new liveloads.

— Generally, cantilever bridges are not made, nor Vierendeel girders nor extended arches because these are not suitable for railway bridges. Sometimes parapet-beams have been built when space was lacking. The structure of a railway bridge always depends upon considerations of an economic character;

b) for the reinforcement A 37, Aq 42 steel is used. Only in the case of A 37, Aq 42 steels are welded joints allowed.

Minimum thickness of the covering : 2 cm.

— Portland cement is used, and pozzolanic cement and high resistance cement. Amount of cement : 350 kg per m^3 of aggregate of sand and gravel; amount of water : 0.30-32 of the weight of the cement. The essential conditions for making good concrete are : good quality materials for the aggregate and water, correct granulation, and exact amount of water, together with care to avoid great variations in temperature and frost.

— Vertical cracks have been noted, due probably to contraction of the concrete near the intermediate supports of the continuous beams, in the central part of the height. To avoid cracks auxiliary reinforcement can be used.

— Vibration of the concrete has given good results. Pervibrators are preferred.

— Vibrated reinforced concrete is practically watertight, but generally bridges are always protected by a covering of asphalt.

— Use has been made of cement with a very high initial resistance mixed with a special product to hasten the setting in order to seal off any cracks occurring during operation;

c) to determine the stresses in the concrete and reinforcements, it is considered that the sections remain flat, the concrete is not under tension, and the ratio between the modulus of elasticity of the steel and concrete is 10 or 8. The working limits for compression in the concrete should not exceed 1/3 of the breaking load in the tests on samples after 28 days (16 × 16 cm cubes).

If the breaking load σ_R is more than 225 kg/cm^2, the working limit σ_c is :

$$\sigma_c = 75 + \frac{1}{9}(\sigma_R - 225) \text{ kg/cm}^2.$$

In the case of the reinforcement the working limit is generally $\sigma_f = \frac{1}{2}$ of the running load.

— To determine the coefficient of majoration for dynamic stresses the formula given by the French specifications are used. Generally this formula is very satisfactory.

— Distribution of the liveload over the width of the bridge : see Chapter IV, Part I.

— Generally in calculating skew bridges, the oblique span is taken. The reinforcements are arranged parallel to the longitudinal axis of the slab.

— For rectangular section bridges and spans up to 10 m, the beams rest directly on the abutments or piers. In the case of longer spans supports are provided consisting of lead and steel plates. If the span is more than 15 m, moveable roller supports can be provided.

— Generally articulations are not used in the case of rectilinear bridges.

The watertight covering consists of 2 layers of asphalt of a combined thickness of 2 cm and then a protective covering of sand 10 cm thick.

— Minimum thickness of ballast on reinforced concrete bridges : 70 cm. In the case of small ballast : 45-50 cm.

— Trials are being made of rails fastened directly to the reinforced concrete deck.

— Relaying the concrete, especially on the deck, has not led to any trouble.

— Generally, reinforced concrete bridges have not given any trouble.

— From experience to date, it may be stated that the use of reinforced concrete

for railway bridges will continue to be extended. Remarkably long spans have already been built, so that in many cases reinforced concrete bridges have replaced metal ones.

PORTUGAL : *Portuguese Railway Co.* has not made any reinforced concrete bridges.

Management of the Harbour and Railways of Mozambique :

a) the Mozambique Railways have always made reinforced concrete bridges.

The oldest reinforced concrete railway bridge is the 5 m bridge 71 km up the Limpopo line, built in 1926. One particularly interesting bridge is the « President Carmona » bridge over the Rio Incomati on the Pimpopo Valley line, which was built between 1938 and 1941. The total length is 500 m in 14 arches with 3 articulations, of 30 m span.

Pneumatic foundations in concrete caissons 12.35 by 10 m and 25 m high. Cost of the work : 15 000 contos in 1940.

— The maximum span for a fully rectangular railway bridge is considered to be 15 m, that of T beams 15 m, and that of box beams 21 m.

— Standard types for the following spans : 10, 12.5, 15, 20, 21 and 30 m;

b) the breaking strength of the steel must be at least 37 kg/mm² with a limit of elasticity of 0.6 of the breaking load and elongation of 24 %. Welded joints are allowed and always used. Minimum covering : 2 cm; near the sea 4 cm.

— The amount of Portland cement usually is 400 kg/m³ with the water needed to get a good working consistency.

— Granulation is checked and the materials must be free from impurities. Great care is taken in making the mix.

— Vibration is carried out by vibrators attached to the framing;

c) the bridges are calculated on the basis of the usual theories.

— The concrete is calculated for compression stresses and the steel for tension stresses.

— The increase for dynamic effects laid down in the regulations is based on experience.

— In calculating the liveload from a 10 t wheel, it is distributed transversely over a rectangle with the following measurements :

$a = 0.11 + (2 \times 0.38) = 0.87$ m;
$b = 1$ m,

equal to a distributed overload of 4 253 kg.

— In calculating skew bridges, the oblique span is taken.

— Moveable roller supports are provided if the span exceeds 20 m.

— On the Mozambique system, only the « President Carmona » bridge has 4 articulations formed of 2 plates which bear against a steel cylinder. The whole of the articulation is boxed in for oiling purposes.

— Watertight and protective coverings are provided as in the case of overbridges.

— The minimum thickness of ballast is 25 cm on the straight; on curves the thickness is 25 cm on the inside, and the depth is increased on the outside owing to the superelevation. Hard stone is used for ballast and must pass through a 4 cm screen.

— The results obtained with reinforced concrete bridges have always been good and this type of bridge is thought to have a great future, especially if the materials are carefully selected and the work properly done.

SWEDEN : *State Railways.*

a) The first railway bridge made was an arched bridge of 35 m span covered with dressed stone. This bridge is still in service.

— Reinforced concrete is now a standard material.

— An interesting arched railway bridge now being designed has a span of 110 m.

— The maximum span for a fully rectangular railway bridge is 8 to 10 m.

— The maximum span for a T-beam or box beam railway bridge is 14 to 16 m with continuous deck.

— The span is the deciding factor in the choice of types other than solid or ribbed slabs;

b) round bars of AC 44 (occasionally AC 37) steel are used or ribbed bars in steel with a limit of elasticity of 40 kg/mm². Welded joints have not been used on railway bridges to date, but there is no objection to their use. They must however be checked by X-ray. To obtain a proper reinforcement, it is necessary to have qualified gangs working under strict supervision. High tensile steels must be used owing to the danger of the concrete cracking. The choice of the steel also depends upon the price. The minimum thickness of the covering according to the State regulations is :

slabs : 15 mm;
beams, arches : 30 mm;
piers, columns : 40 mm,
and at the same time :

round bars : plus the diameter of the bar;

ribbed bars : more than 1.5 of the diameter in height;

side bars : more than 2 times the diameter thick.

— Amount of cement used : 325-350 kg/m³.

The amount of water depends upon the consistency required, the use of vibrators, and the granulation.

The essential conditions for making good concrete are pure aggregate of suitable granulation, internal vibration, qualified gangs, mix decided by laboratory tests to get the right consistency, great compactness and durability owing to the severe climate of Sweden.

— In reinforced concrete railway bridges the usual cracks have been noted. To prevent them or at least limit them, control calculations are made. According to the State regulations if the equivalent coefficient n is 15, the tension of the concrete σ_{bd} of a flexible beam should not exceed :

$$\left.\begin{array}{l}\sigma_{bd} = 0.70\ \sigma_b \\ \sigma_{bd} = 0.30\ \sigma_b + 20\end{array}\right\} \text{ when the concrete has a suitable load on it } \left\{\begin{array}{l}\sigma_b < 50\ \text{kg/cm}^2; \\ \sigma_b \geqslant 50\ \text{kg/cm}^2.\end{array}\right.$$

with a diminution of 20 % for the negative moments of the continuous T-beams and slabs of reinforced concrete with metal joists. The working limit for bridges exposed to smoke is 35 kg/cm².

But these regulations are not very satisfactory, and this further control is carried out. If the tension σ is :

$$0.75\,\sigma_{bd} < \sigma < 1.25\,\sigma_{bd}$$

an expression T is calculated from the following formula :

$$T = \frac{m z \sqrt{d}}{W_b} \cdot \frac{E_a}{\sigma_a}$$

in which :

z = the distance in cm between the centres of gravity of the 2 armatures of tension and compression;

m = number of tension bars;

d = average diameter of the bars in cm;

Ea = modulus of elasticity of the armatures in kg/cm²;

W_b = modulus of resistance of the section relative to the tension without taking into account the existing armatures, in cm³;

σ_a = stresses of the steel in kg/cm².

The calculation should give the following values for T :

	Smooth bars.	*Ribbed bars.*
Permanent load . . .	$T > 50$	$T > 30$
Average of the permanent load and the total load . . .	$T > 30$	$T > 20$

— Internal vibration of the concrete with vibrating points has given good results.

— The use of very compact and durable concrete is the best solution, and at the same time the most economical, for protecting the reinforced concrete against bad weather.

— During the war Swedish production of Portland cement was insufficient for requirements and a substitute type known as E-Cement was used, which required less coal in its manufacture but had a somewhat lower compression strength than Portland cement;

c) the calculation of bridges is based upon the usual theories.

— The working limit of the concrete σ_b are based on the compression strength of samples after 28 days (20 by 20 cm cubes) according to the following formulae :

Class I concrete:

$\sigma'_{B28} = 0.90\ \sigma_{B28}$.

Class II concrete :

$\sigma''_{B28} = 0.80\ \sigma_{B28}$.

If $\sigma_{B28} < 250$ kg/cm² :

$\sigma_b = 0.33\ \sigma'_{B28}$ kg/cm²

If $\sigma'_{B28} > 250$ kg/cm² :

$\sigma_b = 0.25\sigma'_{B28} + 20$ kg/cm².

Maximum values :

Class I concrete :

$\sigma_b \leqslant 120$ kg/cm²;

Class II concrete :

$\sigma_b \leqslant 100$ kg/cm².

In class I concrete, the aggregate is measured by weight, and in class II concrete by volume.

The allowable stresses for the armatures are determined by the limit of flow :

Smooth bars, mild steel :

A 37 limit of flow $\geqslant 2\,200$ kg/cm² :

$\sigma_a = 1\,200$ kg/cm²;

A 44 limit of flow $\geqslant 2\,600$ kg/cm² :

$\sigma_a = 1\,400$ kg/cm².

Ribbed bars : semi-mild steel :

limit of flow $\geqslant 4\,000$ kg/cm² :

$\sigma_a = 1\,900$ kg/cm².

— The majoration formula used for the dynamic stresses is as follows in the case of bridges where the thickness of the ballast is 0.60 m :

$$\varepsilon_1 = 0.9.\varepsilon = 0.9\ \frac{2\,200 + 11\ L}{25 + L}$$

For a thickness (h metres) of more than 0.60 m the formula is :

$$\varepsilon_h = \frac{6 - h}{6} \cdot \varepsilon$$

— The liveload is distributed transversely over a width of 4.50 m.

— Maximum skew allowed : 70°.

In the case of simple bridges on a skew or single track supported beam bridges, the slab is reinforced perpendicularly to the kerb with which the deck is finished off. Bridges with more than one track are built either with a slab for each track or a single slab over the whole width of the bridge. In this case the longitudinal span is taken as the theoretical span.

— Mobile roller supports are used if the span exceeds 12 m. Coefficient of friction : 30 % of the vertical load for sliding supports and 5 % for roller supports.

— Supported beam bridges are made with articulations. Semi-articulations are built on the small walls of the abutment of such bridges. Articulations of a similar kind are provided on the intermediate supports of the structure, or metal ones. Such articulations have stood up well in service.

— Prefabricated parts have not been used but it is thought that they have possibilities for the future.

— Watertight and protective coverings are provided as on concreted decks. In the

case of small bridges on the other hand very compact concrete is used. The parts of the abutments and piers below ground level are also made of very compact concrete.

— The normal thickness of the ballast is 60 cm, on secondary lines occasionally 40 cm. Generally, natural gravel is used for ballast.

— The fastening of the rails directly to the reinforced concrete slab is considered a makeshift arrangement.

Reconcreting has not given any trouble.

— Generally, vertical cracks always occur in the walls of large scale abutments on several track bridges, and to prevent them such abutments are divided up by vertical joints corresponding to the width of the track. In several cases, the concrete has broken away due to too thin a covering being used. These troubles have been cured by filling in with cement mortar.

Our experience of reinforced concrete railway bridges has been satisfactory.

Special attention should be given to the dynamic stresses which are still insufficiently understood.

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PART III.

Pre-stressed concrete and its future possibilities.

The Administrations of the Railways of Finland, Italy, Portugal and Colonies, and Sweden have not used pre-stressed concrete. The Swedish State Railways are of the opinion that its future possibilities are very great.

***

SUMMARY.

General data on the design of railway bridges.

It is true to say that in these latter years the dynamic loadings on which railway bridge design is based have tended to increase.

The axle-loading of the standard train has already reached 25 t and the ratio of the total weight to total length of locomotives has exceeded 13 t/m on lines with heavy traffic, 10 t/m on standard gauge and 8 t/m on narrow gauge lines. All the locomotive axles on the standard train have the same loading and are equidistant; the Italian State Railways are alone in having more lightly loaded axles, and the interval between them is greater.

Uniformly distributed live loads are allowed. While the coefficient of increase for dynamic effects is as yet in an experimental stage, this is not the case, however, for the other dynamic stresses, on which a certain unity of views has already been reached. The effects of temperature and wind will be considered in terms of the local conditions prevailing in the various countries.

There is no experience to hand at present regarding creep. Shrinkage will be considered as being produced by a drop in temperature of 15°-20° C.

The fatigue effect of repeated loading in the case of metal bridges is allowed for by making a certain reduction in the permissible stresses; this factor is not generally taken into account in concrete bridges.

The decision as to whether a bridge shall be built of metal, concrete, natural stone or reinforced concrete depends on various considerations, such as: economy, geographical location, load admissible on ground, height of structure, availability of materials and aesthetics.

Generally speaking, with regard to aesthetic considerations, no recourse is had to the collaboration of an architect, save in the case of special structures.

When, in addition to primary stresses, a metal structure is subject to bi-axial stresses, either a system of ideal stresses or Beltrami's Theory is used. Where bi-axial stresses occur in a welding seam, the Swedish Railways apply a formula, derived from Beltrami's Theory, which was submitted by a Commission charged with drafting new standard specifications.

Metal railway bridges (Figs. 6, 7, 8).

With regard to *main girders,* simple or continuous are generally preferred; other types are chosen solely when dictated by special circumstances, such as: inordinate length of span or height of structure, or by aesthetic reasons.

For a span of up to 30 m (98 ft.), *plate girders* are favoured as being the simplest, the most practical and the most economical. Height is 1/10th of span, but special road traffic restrictions make it possible to limit the height to 3 m (10 ft.).

Where *lattice girders* are concerned, preference goes to girders with parallel flanges and triangular openings as these are isostatic, simpler and more economical.

Generally, in the case of double track lines, one double track bridge is preferred because its weight is 9/10ths that of two separate bridges.

With regard to skew bridges, however, two single track bridges are favoured by reason of the great precision needed in design.

Only two Administrations (Finland and Sweden) have adopted *electric welding* frequently in the construction of plate girders and have not experienced any difficulties. Sweden makes use of special section ribbed girder flanges. In general, welding is not yet widely used and this is particularly true in the case of lattice girders.

Fig. 6. — *Swedish State Railways.* — Viaduct with 19 spans, from 42 to 50 ft.

The welding of lattice girders, where it is practised, is effected in the workshop only — welding during site assembly is not permitted and the joints are rivetted.

The maximum welded thickness is 50 mm (1.97 in.); however, the new Swedish specifications now being prepared permit welding up to a thickness of 70 mm (2.76 in.) in the case of A 37 to A 44 quality steels (to be standardised for thick-

Fig. 7. — Bridge on a private railway in northern Sweden : main span 113 ft.; continuous approach-spans of 34 to 51 ft.

Fig. 8. — *Swedish State Railways*. — Bridge with main span of 200 ft. partly supported by flexible arcs.

nesses exceeding 50 mm) and up to 65 mm (2.56 in.) in the case of A 48 to A 52 quality steels (to be standardised for thicknesses exceeding 30 mm [1.18 in.]).

« U » or « I » section members have been used for welded lattice girders; generally, the qualities of steel employed are A 37 to A 44, which have a limit of elasticity of 21 kg/mm² (13.33 tons per sq. in.) and an elongation of 21 %. The Italian State Railways prefer rivetted construction as, for reasons of economy, they use Aq 50 steel which, in their opinion, is not so well suited to welding.

Special steels or light alloys are not used.

Two « composite » type bridges have been built, one in Finland and the other in Sweden. In Finland, the structure consists of steel main girders with a deck of reinforced concrete 25 cm (9.8 in.) thick (fig. 9). Connection is effected by embedding the top flanges of the girders in the concrete slab; in Sweden, the concrete slab rests directly on the main girders, which are designed to support the full load. Connection is effected by iron bars welded to the girders. Stresses in the concrete are controlled if the concrete itself has been taken into account in the calculations.

Generally speaking, roller bearing-supports are required for spans exceeding 12 ÷ 15 m (39 ÷ 49 ft.). Special arrangements providing for the expansion of the rails are made on all large spans; such arrangements are usually located at the ends of the bridge.

Where *decks are of all-metal construction*, the track is laid on sleepers as these ensure better lateral stability and are easier to replace.

Connection of rail bearers to cross-girders is effected by the rail bearers being fitted into the cross-girders; generally, such connections are rivetted, but the Swedish Railways also obtain successful results with electric welding of connections in the assembly of rail bearers to cross-girders and cross-girders to main girders. Where the track comes onto the metal deck of a bridge sleepers are used; these, in the case of skew bridges, are laid in a fan-shaped pattern. As a general rule, rail-joints are avoided on bridges in order to lessen dynamic effects. The maximum length to which rails are welded is 300 m (984 ft.). Check rails are often used on bridges with a span exceeding 10 m (33 ft.) as they are held to increase the safety of traffic.

Very heavy *concrete slabs* are not considered advantageous from the economical point of view. The minimum depth of gravel or broken stone ballast beneath the foot of the rail is 40 cm (15.7 in.). Generally, the top surfaces of concrete slabs are waterproofed either with two thicknesses of jute-cloth or with tarred felt and asphaltic coatings. Protection is achieved by a 5 cm (2 in.) thick layer of concrete or by a 4 cm (1.6 in.) layer of reinforced concrete.

Masonry railway bridges.

No masonry railway bridges have been built in Sweden in recent years. In Italy and Portugal, however, many have been constructed especially to replace metal bridges.

Construction of masonry bridges depends on the availability of materials and each Administration uses a method of calculation and a building technique adapted to the particular conditions obtained in the country concerned.

As a general rule, one may say that when a masonry arch has been designed as articulated, the articulations are effectively constructed. (Fig. 10.)

Thick masonry arches are usually constructed with several separately laid rings; these rings are bonded together by means of iron bars. The waterproof bituminous coatings are put directly either onto the extrados of the arches or onto the weak concrete filling between the spandril walls.

The drain pipes, minimum diameter 10 cm (3.9 in.), are positioned through the arches themselves; the maximum distance

between these pipes being 30 m (98 ft.). The dynamic effects of the live load are not normally taken into account in the calculations for the design of masonry arches as the permanent load is of much greater magnitude than the live load.

full load, and the live load is distributed over a maximum width of 5 m (16 ft.) in the case of single track bridges and of 9 m (30 ft.) in the case of double track bridges. The minimum clear distance between the edges of flanges of adjacent girders is 8 cm

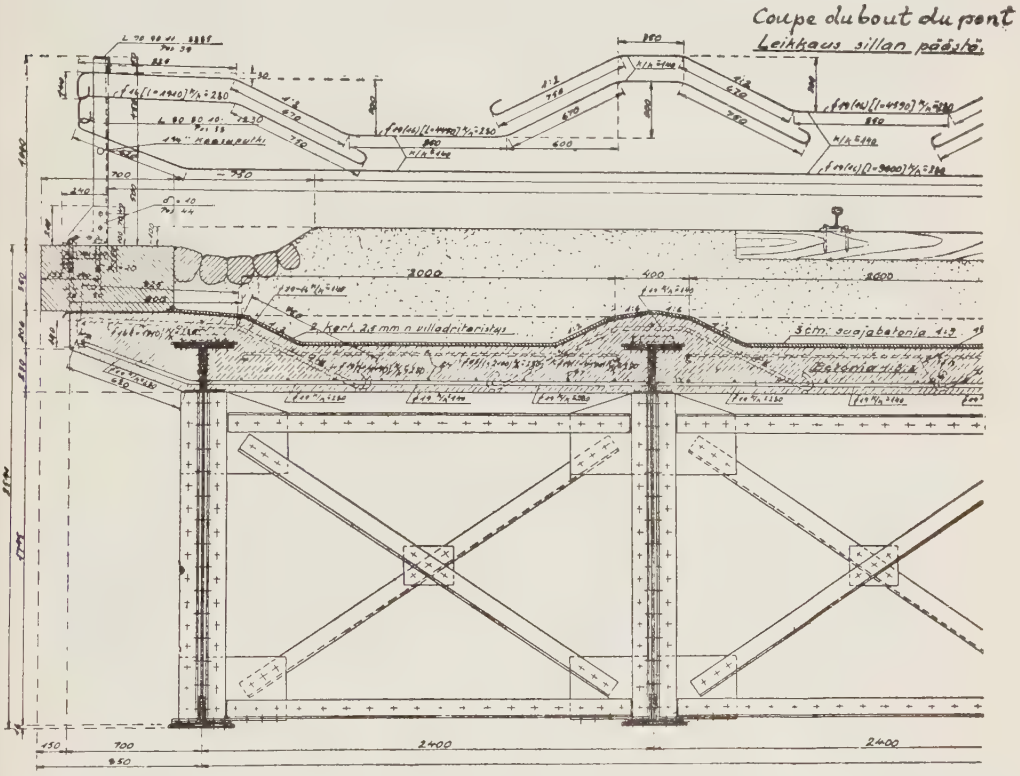


Fig. 9. — Bridge over Maaherrankatu (name of street) at Kuopio (*Finland*). — Detail of cross section. Scale 1 : 40.

Railway bridges with girders encased in concrete. (Fig. 11.)

This form of construction is advantageous where the permissible depth of the structure is limited and it is economical for spans up to 20 m (66 ft.); use is made of standard designs in this connection. The maximum span reached is 16.75 m (55 ft.). In calculations for this type of construction, the metal beams alone are held to carry the

(3 in.). Transverse reinforcement (ties) is culated in a purely empirical manner. In the case of skew bridges, the girders are positioned parallel to the skew span and are calculated accordingly. In the case of a double track bridge, a single slab is preferred, as the live loads are then spread over a greater width. The girders are either completely encased or have the undersides of their lower flanges exposed.

Rail-type supports of the abutments are used for spans in excess of 8 to 10 m (26 to 33 ft.). The minimum depth of ballast is 40 to 50 cm (15.7 to 19.7 in.). Waterproofing is carried out with bitumen and the maximum slope for the drainage of surface water is 1 in 50. The maximum distance between drain pipes, which have a minimum diameter of 10 cm (3.9 in.), is intermediate supports having rigid frames forming a single unit with thin reinforced concrete piers. Sliding roller bearings are used for spans exceeding 20 m (66 ft.). For simple reinforced concrete slabs, bearings are steel plates. Dynamic effects of the live load are generally taken into account in the formulae. The joint at the abutments between the roadway and the bridge is made

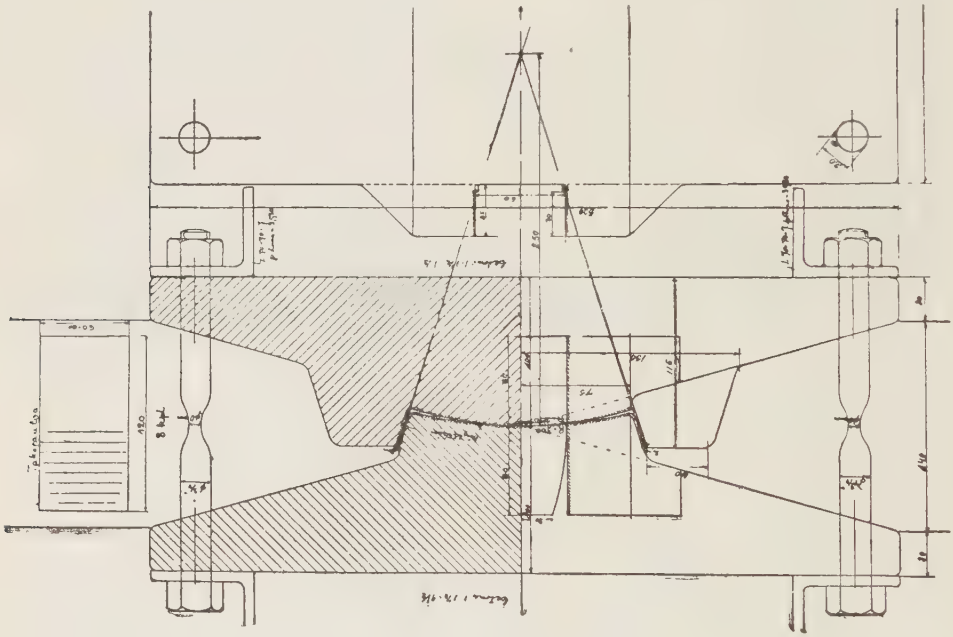


Fig. 10. — Articulation of the bridge at Pahakoski (*Finland*). — Scale 1 : 5.

equal to the span. Occasionally, in cases of limited depth of construction, track rails have been fixed direct to the girders. As a general rule, the increase for dynamic stresses is taken, into account as for reinforced concrete bridges.

Road bridges and over-bridges.

Concrete or reinforced concrete are preferred for reasons of economy and in view of the lesser height of construction; standard designs are used in certain cases. For over-bridges located within stations, preference goes to single long spans without with a special plate arrangement. The decks of over-bridges are waterproofed in the same way as those of railway bridges and the wearing surface is usually of reinforced concrete, asphalt or asphalt blocks. Railway or tramway rails are fixed in the slab, with sleepers in the macadam. In Portugal and Sweden, such constructions are generally carried out by the Highway Departments.

Piers and abutments.

Preference is given either to solid piers in natural stone with granite or concrete

bedstones or to more or less slender reinforced concrete piers with reinforced concrete bedstones Abutments are generally built with wing walls returning from the ends of the abutments as this system is more advantageous from the economical point of view and also more effectively withstands the earth pressure. Provision is made for all horizontal forces acting at deck level to be transmitted to the foundations. Fixed bearings are frequently located on piers.

Retaining walls.

The earth pressure to which a retaining wall will be subjected and the capacity of the ground to resist foundation pressures are determined with the aid of semi-empirical formulae; however, in special circumstances due to the size of the works or to the nature of the ground, more modern methods, based on soil mechanics, are used for ascertaining these pressures.

Tunnels.

It is not a general practice to protect the concrete linings of tunnels against deterioration by smoke. On electrified lines, special measures are adopted to safeguard against leakage of current or short circuits due to seepage of water. These measures consist of protecting the masonry with waterproof coatings and, in the case of cracks occurring, of injections of cement.

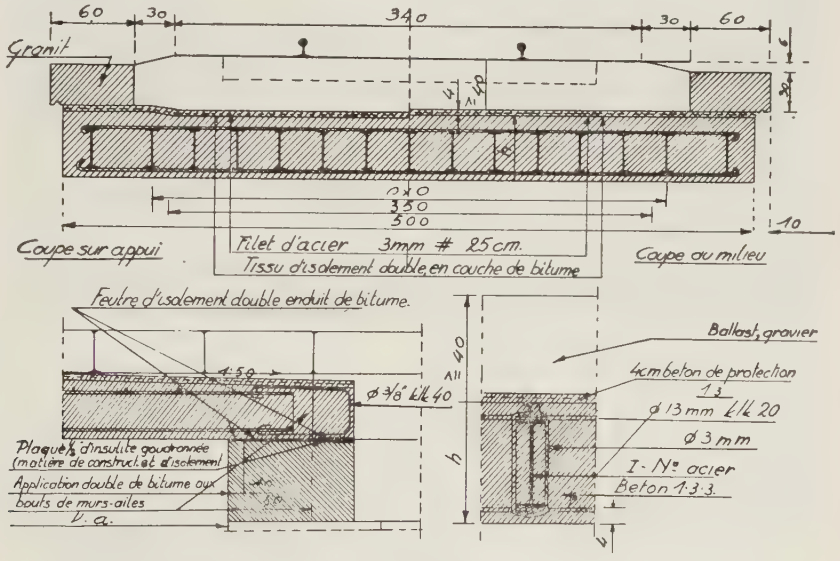


Fig. 11. — *Finnish State Railways.* — Bridge with girders encased in concrete.

Platform roofs. (Figs. 12-13.)

The materials preferred for the construction of platform roofs are reinforced con-

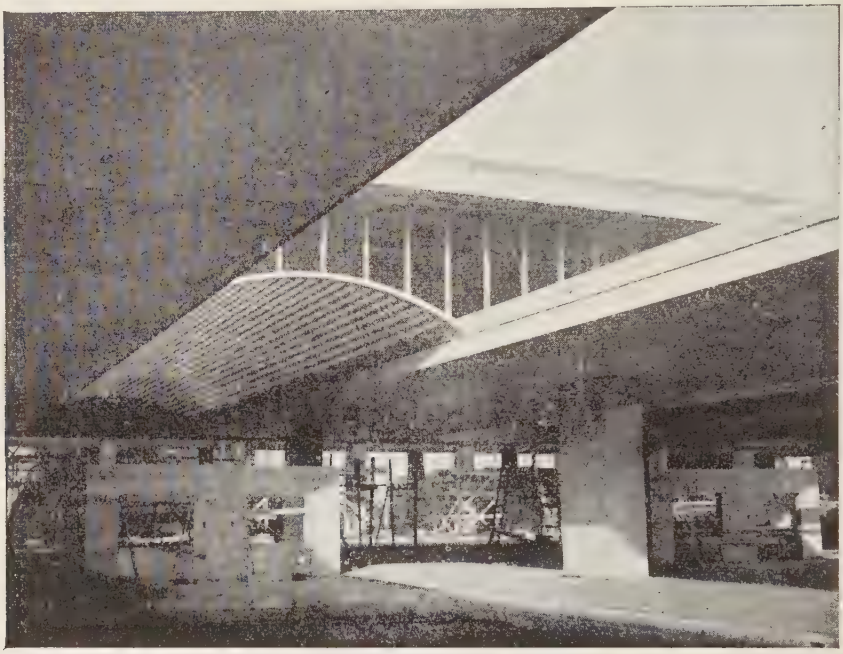


Fig. 12. — *Italian State Railways.* — New station at Rome : Skylights at ends of platform roofs.

Fig. 13. — *Swedish State Railways.* — Experimental wooden platform roof.

crete, steel and wood. Occasionally, roofs covering platforms have glazed extremities. Assymetric loadings taken into account in calculations are usually those brought about by snow and wind pressure. The Swedish Railways allow for an horizontal wind pressure of 100 to 125 kg/m² (20 to 25.7 lbs. per sq. in.) on the vertical projection, for stability and for upward thrust, an upward vertical force of 50 to 65 kg/m² (10 to 13 lbs. per sq. in.) on the horizontal projection. The Italian State Railways allow for a positive wind pressure of 40 kg/m² (8 lbs. per sq. in.) and a depression (negative pressure) due to wind also of 40 kg/m².

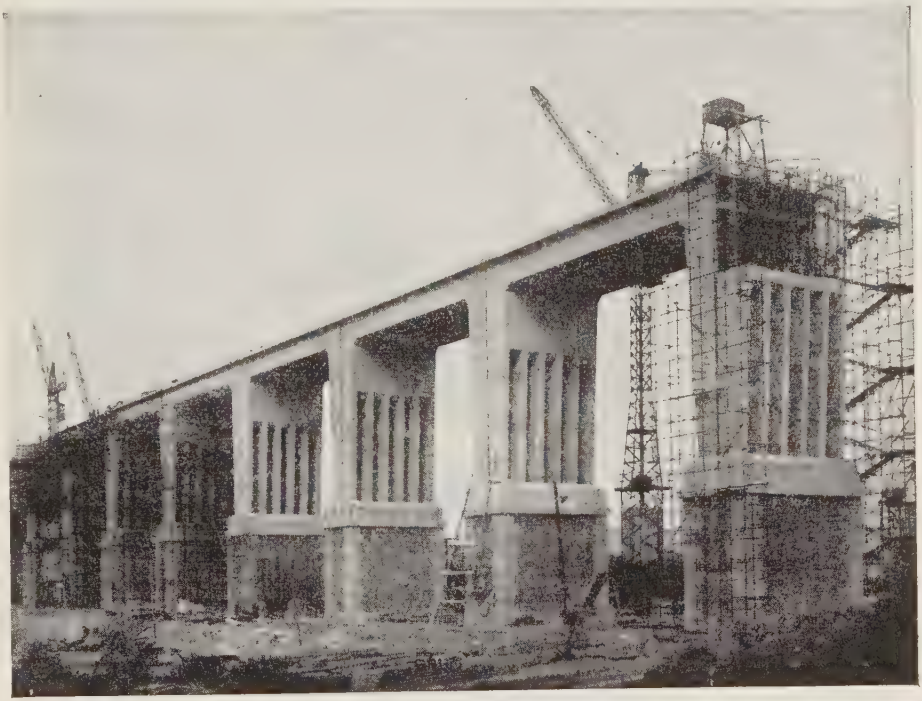


Fig. 14. — *Italian State Railways.* — Desenzano viaduct : 16 spans of 57 ft.

Testing of bridges.

Live load tests are generally carried out before the bridge is put into service in order to ascertain whether actual stresses and deformations are the same as those allowed for in the calculations.

Tests are both static and dynamic. Sometimes tests are carried out when the bridge is being used normally by traffic in order to see how it is standing up to operating conditions. Live load tests are usually made by the Bridges and Highways Dept. or Service. Recording instruments are used in particular for measuring the dynamic effects of live loads or for controlling the effect of long term developments.

Much importance is attached to bridge testing in order to ascertain the frequency of vibrations, to keep a check on them during their life, and in order that the results of such tests may be taken into account when designing similar structures.

Results obtained in the construction of railway bridges in reinforced concrete.

(Figs. 14, 15, 16, 17, 18.)

According to replies received, the first reinforced concrete railway bridge was built in Italy in 1908; it has a 10 m (33 ft.) span and is still in service. Reinforced concrete may be taken as having left the experimental stage in 1920 and today the use of this material for constructions is assuming wide proportions; with regard to prestressed concrete, future possibilities are excellent and developing to a large extent.

The maximum span for a railway bridge comprising rectangular reinforced concrete beams is 10 m, where « T-beams » or box beams are used, the maximum span is 25 m (82 ft.) and for continuous beams with T-girders, 44 m (144 ft.).

For single spans up to 21 m (69 ft.) standard designs are used. Structures with more or less surbased arches, with rigid set in frames or with articulation, and structures with parapet-girders have also been adopted.

The steels generally used are : A 37, Aq 42, Aq 44 in circular section bars or ribbed bars.

Fig. 15. — *Italian State Railways.* — Santo Spirito viaduct : over-all length 2297 ft. Main span : 212 ft.

Welded joints are permitted as a general rule.

The essential requirements to ensure a good and satisfactory reinforcement assembly are : availability of qualified gangs with strict supervision. The use of high resistance steels is limited by the cracking of the

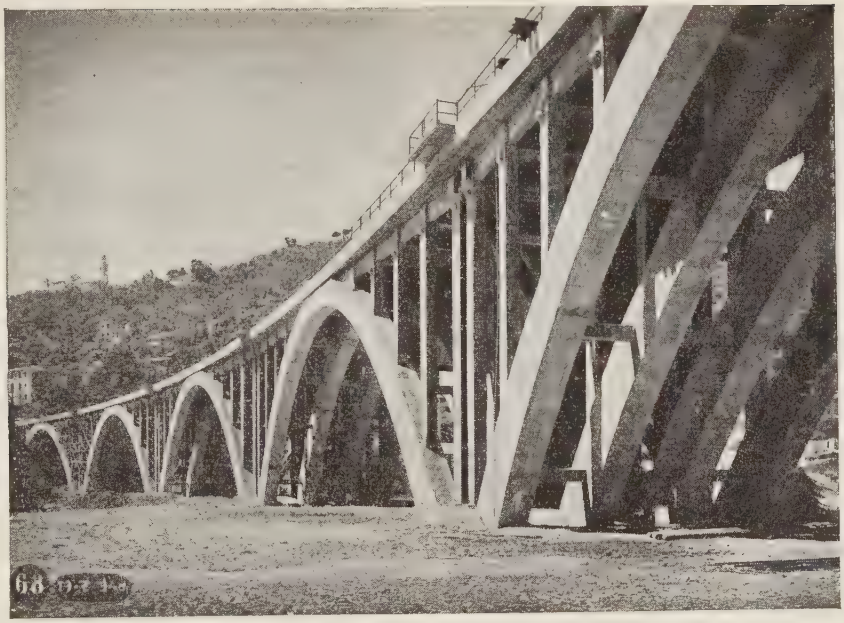


Fig. 16. — *Italian State Railways.* — Recco viaduct : 6 spans of 144 ft. and approach spans of 46 to 62 ft.

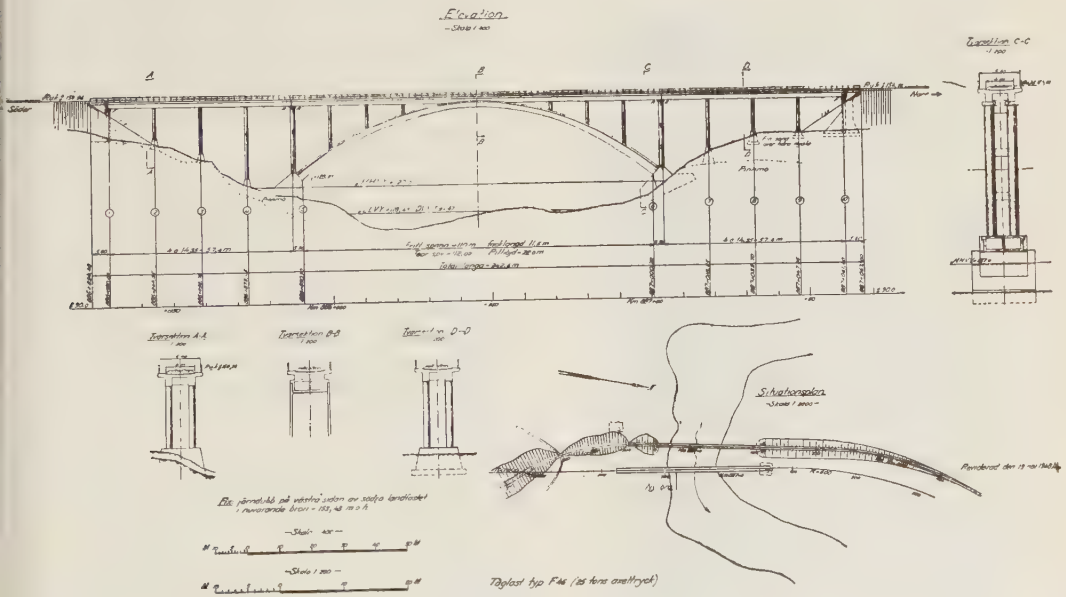


Fig. 17. — *Swedish State Railways.* — Projected reinforced concrete bridge. Main span 361 ft.

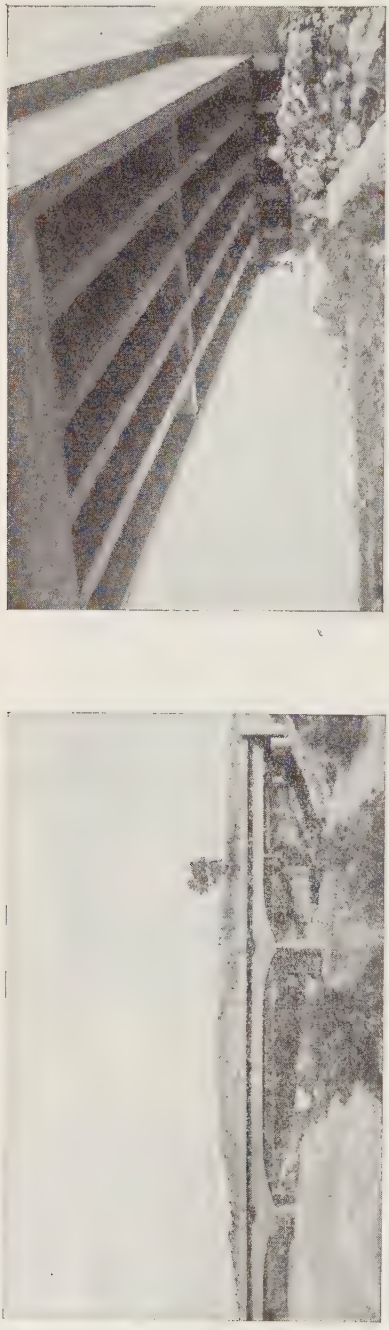


Fig. 18. — *Italian State Railways.* — Continuous span bridge (112 — 44 — 112 ft.).

concrete. In the case of the railway bridge over the Ombrone (Italy) with continuous girders (34.25 m - 44 m - 34.25 m ie.: 112 ft. - 144 ft. - 112 ft.), Aq 50 quality steel was used and the joints were welded.

The minimum thickness of the concrete encasement is 15 to 20 mm (0.6 to 0.8 in.) for slabs, 30 mm (1.2 in.) for girders and arches, 40 mm (1.6 in.) for piers and, for circular section bars, a thickness equal to the diameter of the bar; where ribbed bars are used, the thickness of the concrete is 1.5 times the diameter.

The proportion of cement to other aggregates in the concrete is 300 to 400 kg/m³ (18.7 to 24.9 lbs. per cub. ft.), the water content depends on the desired consistency for work. Grading of the aggregates is generally controlled and a good consistency is required.

The essential requirements for producing a good concrete are : good quality cement, aggregates and water, correct grading of the aggregates, a strictly controlled water content, avoidance as far as possible of large scale variations in temperature together with protection against freezing during building operations, careful manufacture, use of proportions of ingredients as fixed by laboratory research and vibration of the concrete.

Cracking of reinforced concrete, due probably to shrinkage, has been observed particularly in continuous girders and it occurs mainly in the immediate vicinity of intermediate supports and in the central portion of the height. To avoid or at least limit cracking either a secondary or auxiliary armature may be provided or test calculations, based on SALIGER's theory on cracking, may be made.

Excellent results are obtained from the vibrating of concrete provided this procedure is applied correctly; various types of vibrators are used for this purpose.

No special materials are introduced into the concrete to improve its workability and consistency.

The best method of preventing deterioration of reinforced concrete from severe weather conditions is to give it a heavy consistency and good durability and to protect it by waterproofing.

The types of cement used are : Portland cement, cement mixed with « puzzolane » and high resistance cement. In order to avoid cracking of the concrete during work, use may be made of ultra high resistance cement mixed with a special material to make it set rapidly.

As a general rule, the calculations for the design of railway bridges are based on the generally accepted theory for reinforced concrete design, compression stresses being taken into account for the concrete and tractive stresses for the steel armature.

The maximum permissible internal action of concrete is based on the resistance under compression of test pieces over a period of 28 days and generally the limit figure is 1/3 or 1/2.5 of breaking point. Where breaking point is above 225 to 250 kg/cm² (1.4 to 1.6 tons per sq. in.), the permissible stresses in the concrete may reach 110 to 120 kg/cm² (0.7 to 0.8 tons per sq. in.).

Permissible stresses in the reinforcement are determined on basis of the limit of expansion for A 37 mild steel the limit figure is 1 200 kg/cm² (7.6 tons per sq. in.), for A 44 steel : 1 400 kg/cm² (8.9 tons per sq. in.) and for semi-hard steel : 1 700 kg/cm² (10.8 tons per sq. in.).

The formulae giving the increase in view of the dynamic effects of the live load take into account either the depth of ballast and the span, or the span and the ratio of the permanent compression to the live load.

These formulae are normally based on experience and are satisfactory.

The transversal distribution of the live loads over the width of the bridge is 3 to 5 m (10 to 16 ft.).

In the case of skew bridges, the skew span is generally taken into account and the reinforcement is mounted parallel to the longitudinal axis of the concrete slab. The maximum oblique angle accepted is 70°.

Bearings are used for spans in excess of 8 to 10 m (26 to 33 ft.) sliding bearings for spans up to 15 to 20 m (49 to 66 ft.) and roller or pendular bearings where the span exceeds 15 to 20 m. The coefficient of friction is 30 % of the vertical load for sliding bearings and 15 % for roller bearings.

The articulations used have given satisfaction.

Prefabricated reinforced concrete units have not been employed in bridge construction.

As a general practice, waterproofing and protective coverings are provided as on bridges with concrete decks.

The minimum thickness of ballast is 40 cm (15.7 in.). Tests are being made of rails fixed direct to the reinforced concrete slab, but this form of construction is looked upon as a last resort. Generally speaking, repairs to the concrete work have not caused any great trouble and reinforced concrete bridges have not been subject to any particular kind of damage.

Pre-stressed concrete and its future possibilities.

No bridges have as yet been built of pre-stressed concrete.

[621 .431 .72 & 625 .616]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION XIV.

Change-over from steam-locomotive traction to Diesel traction.

REPORT

(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Denmark, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburg, Netherlands and Colonies, Norway, Poland, Portugal and Colonies, Rumania, Spain, Sweden, Switzerland, Turkey and Yugoslavia),

by M. Diegoli, Dr. Ing.,

Inspecteur en Chef au Service du Matériel et de la Traction des Chemins de fer de l'État Italien.

INTRODUCTION.

During the last dozen years or so, steam traction which held undisputed sway during the last century, in spite of its progressive improvement and development, has found itself in competition with more up to date methods, that is electric traction and Diesel engine traction.

Each of these special methods has its own advantages and difficulties; it is only possible to choose between them by taking into account the whole of the operating requirements, economic factors and local characteristics of the railway in question.

Diesel traction, which recently has undergone such development in North America, has also been the subject of great interest in Europe and dependent countries during the last twenty years. Its progress has been very rapid, extensive and concrete in the case of light traffic whilst, after trials of considerable interest technically in the field of heavy traction, it can be said that it is only since the war that it has become a part of the normal train working in this case also.

The question forming the subject of the present report was intended to throw light, by means of investigations spread over a large number of railways, on the reasons for which many Administrations have decided to change over to Diesel traction or are investigating its possibilities, together with the results and conclusions at which they have arrived.

The questionnaire sent in August 1949 to 81 Administrations, members of the Congress Association, was based on this idea. 26 replied, but only 18 were able to give positive data.

Owing to the extent of the subject, it has been considered advisable to divide it into three parts :

— locomotives for line working;
— shunting locomotives;
— railcars.

In this way it was easier to group the different applications according to their typical characteristics, which differ considerably from one group to another, so that it would be difficult to classify them all together.

The special characteristics and requirements of the operating rather than direct considerations of a geographical nature make it expedient to divide up the railways covered by the present Report into two groups : European, and Non-European, for each of which the problem of Diesel traction is appreciably different.

A. — Locomotives for train-service.

QUESTION 1. — *Do you have Diesel locomotives in regular service, on trial or in study? If so, how many and since when?*

QUESTION 2. — *Which are the practical reasons that brought you to this decision?*

Table A sums up the development of Diesel locomotives for the line services on the different railways concerned. However, a few detailed remarks appear to be called for, based on the data sent in by the Administrations concerned.

— The *S. N. C. F.* only has two 4 000 HP Diesel-electric train locomotives, put into service in 1937 in order to make a trial of the new methods of traction not fully developped at that date, to haul express passenger trains.

In addition they are going to carry out trials of Diesel traction on small lines to haul medium sized goods trains, with 150, 360 and 600 HP locomotives similar to those used for shunting in the yards. These new services are justified by the savings expected compared with steam traction.

— The *Danish State Railways* have made use of six 250 HP Diesel locomotives since 1927, but they were taken out of service in 1939 as they were not sufficiently powerful or fast.

In 1929 they bought 2 Diesel-electric locomotives with 425 HP engines, afterwards replaced by a more up to date 500 HP model, and in 1932 two 900 HP Diesel-electric locomotives which are still in service.

The object in view was greater economy, more suitable services, a greater degree of user, no need for turntables and large sheds, and the other advantages of Diesel traction compared with steam traction.

— The *Swiss Federal Railways* have had two 1 200 HP Diesel-electric locomotives in service since 1939, and other Diesel locomotives are being designed for shunting services and also for emergency use if there is a breakdown in the electric traction. They were encouraged to do so owing to the fact that Diesels appear to be more economical than steam locomotives.

— The *Austrian Federal Railways* have had Diesel locomotives in service on their narrow gauge lines since 1930, and on the standard gauge lines since 1933, but none of them of very powerful types.

They have twenty 1 000 HP Diesel locomotives under construction.

Diesel traction was being tried out 25 years ago on the *Italian State Railways*, with the construction, for experimental reasons, of two locomotives, one (Hocke-Ansaldo) with direct rod and crank drive, 1 000 HP Junker type engine, with a compressed air injection device using the pump as engine. The trials gave very promising results, especially as regards the remarkable flexibility of the engine, which worked very well at as low a speed as 6 km/h. (3.7 m.p.h.), but were interrupted by a serious accident to the mechanical part, and were not resumed owing to financial difficulties. The other locomotive (Zarlatti) with pneumatic drive, making use of the compressed air saturated with steam in the open cycle, was found to have a low power/weight ratio during the trials, and as other of its characteristics were also unsatisfactory it was given up.

Three Diesel-electric locomotives were built in 1939 for the Massaua-Asmara

(Eritrea) line with supercharged engines, developing 600 HP at an altitude of 2 400 m (7 900 ft.). The object was to have greater power, and consequently speed than with steam traction, whilst having a weight suitable for the line in question, which includes 50 km (31 miles) of line on a continuous gradient of 35 °/₀₀.

The Italian State Railways now have under study Diesel locomotives with a power of 1 000 HP at the tread and an axle load of 15 tons, and speed of 100 km/h. (62 miles).

— The *Portuguese Railway Company* has put 24 Diesel-electric locomotives into service, on account of the economy of these locomotives, and the difficulty of importing coal.

— The *Norwegian Railways* only have one 2 000 HP Diesel locomotive in service with hydraulic drive, built in 1942. This locomotive was bought for trial purposes for use on the Bergen line where steam traction involves much inconvenience owing to smoke in the many, long tunnels.

The use of Diesel locomotives is particularly useful for obtaining high speeds over the long, heavy gradients on this line, two units being used for the mountain section.

— The *Swedish State Railways* have not yet made any trials of Diesel locomotives for line working, but the question is now under consideration because this method of traction appears to be more economical than steam.

— The *Belgian National Light Railways Co.* operates a metre gauge system of approximately 5 000 km (3 100 miles), of which 3 500 km (2 200 miles) are electrified. On the latter, passengers are transported by means of railcars, whilst the goods services (10 % of the total receipts) since 1947 have been operated by Diesel tractors, instead of steam locomotives, 46 of which are already in service and 22 under construction, of a 19 t type. Another 30 t type is now being designed.

This substitution took place in order to reduce the cost of goods transport, speed up the trains, and increase the flexibility of the services.

— The *Algerian Railways* have had a 1 200 HP Diesel locomotive in service since 1933, and also a 750 HP one, as prototypes for trial purposes. Since the war it was necessary to consider replacing the stock of steam locomotives, which were all completely worn out, and as electrification was not possible, the Diesel-electric engine seemed to be the best solution. At the present time, in addition to the two locomotives mentioned above, they have fifteen 1 500 HP units (since 1946), twenty-five 1 500 HP units (1947) and fifteen 1 000 HP units (1948) in service.

— The *Gafsa Railways* (Tunisia) has 17 Diesel-electric locomotives under construction of about 600 HP for their metre gauge lines. It was decided to replace the steam locomotives by the above for the following reasons :

— better output, i.e. lower cost of transport per tonne-km;

— driven by a single man : saving in staff;

— simplified maintenance;

— doing away with the transport of coal and water;

— suppression of most of the water towers and water purifying plants;

— saving in labour for handling the fuel;

— improvement in the average speed of the trains (no time required for watering or cleaning the fire during the run);

— need to replace the steam locomotives which had been in service since 1908 to 1914, and were needing ever increasing repairs;

— suppression of turntables.

— The *Franco-Ethiopian Railway* has 12 Diesel-electric locomotives on order for 1.067 m (42 in.) gauge lines; if the results prove satisfactory, they intend gradually

Railway	Gauge	Diesel locomotives		
		in normal service	under trial or being built	
S. N. C. F.	Standard —	2 of 4 000 HP —	— of 150/360/600 HP	1 1
Danish State Railways	Standard Standard Standard	6 of 250 HP 2 of 500 HP 2 of 900 HP	— — –	1 1 1
Swiss Federal Railways	Standard Standard	2 of 1 200 HP —	— of 1 600 HP (800 × 2)	1
Austrian Federal Railways	Narrow Standard Standard	8 of 145 — 210 3 of 300 —	— — 20 of 1 000 HP	193 li
Italian State Railways	Narrow Standard	3 of 600 HP —	— of 1 200 HP	k
Portuguese Railways Co.	Standard	24	–	1
Norwegian State Railways	Standard	—	1 of 2 000 HP	1
Swedish State Railways	Standard Standard Narrow	— — —	of 1 200 HP of 1 600 HP of 800 HP	
Belgian National Light Ry.	Meter	46 of 160 HP –	— 22 of 160 HP 1 of 300 HP	
Algerian Railways	Standard Standard Standard Standard Standard	1 of 1 200 HP 1 of 750 HP 15 of 1 500 HP 25 of 1 500 HP 15 of 1 000 HP	— — — — —	
Gafsa Railways	Meter		17 of 600 HP	
Franco Ethiopian Railways	1.067 m	—	12	
Madagascar Railways	—	5 of 625 HP	7 of 625 HP	194
Matadi-Léopoldville Ry.	0.165 m 1.067 m	— —	4 low power units, 8 of 1500 HP	

ght in tonnes /	in working order	Weight in kg/HP	Drive	Utilisation	Remarks
	230	58	Electrical	Express passenger trains.	Prototype under trial.
	—	—	Mechanical	Goods trains of moderate tonnage over small lines.	Similar motors to those on the locomotives designed for yard shunting services.
	—	—	Mechanical	Light passenger trains.	Out of service since 1939.
	61.3	68	Electrical		Locomotive with luggage compartment.
	107.6	118	Electrical		
	65	54	Electrical	—	A Diesel electric locomotive is being designed for shunting, and for emergency services when there is a breakdown of the electric traction.
	108	68	Electrical		
0.9	12.85 ÷ 22	89 ÷ 105	—	Light passenger and goods trains.	—
	30.5	102			
	67	67			
	46	77	Electrical	On colonial lines. Passenger and goods on secondary lines.	Under consideration.
	—	—			
	—	—	Electrical	—	—
	85	42.5	Hydraulic	On mountain lines with many tunnels.	Prototype under trial.
	56	46.5	—	—	Being designed.
	81	—	—		
	46	51	—		
	19	—	Mechanical	Goods trains and mixed traffic.	
	19	—	Mechanical		
	30	100	Mechanical		
	101.6	84	Electrical	For all services.	Prototype under trial.
	73	97	Electrical		
	124.6	83	Electrical		
	124.6	83	Electrical		
	103.1	103	Electrical		
	51	85	Electrical	For all services.	
	—	—	Electrical	For all services.	
	61.5	99	Electrical	Passengers and goods.	
	28	—	Electrical	—	
	—	—	Electrical		

to replace all their steam locomotives. This is on account of the poor quality water in the Gibuti region, the difficulty of getting water in the dry season, and the high cost of coal.

— The *Madagascar Railways* have five 625 HP Diesel-electric locomotives in normal service since 1943-46 and 7 units of the same type are on order. The object is to have more powerful units available, to deal with the growing traffic on the single track line where the number of trains run is necessarily relatively small, to obtain greater regularity in working, and to be independent of refuelling posts en route both as regards coal and water.

— The *Matadi-Leopoldville Railway* has 12 Diesel-electric locomotives on order, 4 of them of small power for the 0.615 m (24.2 in.) gauge lines, and eight of 1 500 HP for the 1.067 m (42 in.) gauge lines. The reasons for the change-over were in particular the relatively high cost of coal in the Congo and the difficulty of transporting it over the system, whereas fuel oil is brought in by pipe-line from the ports.

It is also expected to achieve economy in fuel and maintenance.

QUESTION 3. — *Which are the results (if possible in figures and in comparison with steam traction) you actually obtained, and especially on the following points :*

a) *average monthly mileage; average percentage of availability and utilisation; time for shopping and periodic inspections, daily inspections and repairs, ready for service (available) and service (working) to be considered separately. Time in minutes lost and made up during a month by a locomotive of a certain type;*

b) *average and maximum length of scheduled locomotive-runs in normal service without engine change;*

c) *nature and frequency of troubles that may lead to disturbances in train-service;*

d) *average percentage of utilisation of the locomotive-power;*

e) *first costs, based on actual prices, total and per rail HP, and resulting annual charges;*

f) *operating costs per mile, composed chiefly out of repairs, fuel, lubrication, other supplies, maintenance, crew-wages and social charges, specified if possible for different types in service;*

g) *total repair-costs per unit of fuel consumed, and all further information that might be of use for this purpose;*

h) *simplicity and surety of the regulation during the run of the train;*

i) *miles performed between two general overhaulings; to be given separately for the Diesel-motor, the transmission-system and the other parts of the locomotive;*

j) *amount and costs of fuel, consumed per rail HP hour using the locomotive with full load.*

As the replies to question 1 showed, the Railway Administrations to which this questionnaire was sent who have had Diesel locomotives in service long enough to be able to reply to the above questions are not very numerous. In addition it must also be pointed out that owing to the specific difficulties of the question, the replies received were not homogeneous and comparable, i.e. such as could be summed up in table form; consequently they are reported below with some comments thereon.

S. N. C. F.

a), b), c) The two 4 000 HP Diesel-electric locomotives put into service in 1937 had run a total of 378 000 km (235 000 miles) at the beginning of the

war. They could not be run during the war owing to lack of fuel, but were put into service again after the liberation, as far as the fuel oil available permitted. During the last months they have once again been running the same services as before the war: the total mileage for the two units on the 1st October 1949 amounted to 1 708 493 km (1 061 637 miles).

On the Paris-Lyon line, 600 t express passenger trains are normally hauled by type 231 steam locomotives on the easy sections and type 240 or 241 on the difficult sections (8 mm = 8 $^{0}/_{00}$).

In general the Diesel locomotives have worked with great regularity and accidents during the run affecting the train service have been very few.

As regards the services worked by these locomotives, the following data may prove of interest, concerning a period of 147 days (April-September 1949) during which one of these two locomotives was put into service on the Paris to Lyon and back run (1 024 km = 636 miles). During this period, this locomotive should have made the run 147 times = 150 528 km (93 534 miles). For various mechanical reasons it only actually ran 124 454 km (77 333 miles) during the 133 days, not taking into account repairs which were made outside the period in question, its availability in service was therefore 90 % $\left(\frac{133}{147}\right)$ and its user 82 % $\left(\frac{124\,454}{150\,528}\right)$.

No figures can be given for availability including repairs, because an adequate store of spares was not available for repairing these two single units;

d) on the Paris-Lyon run as a whole, the average power developped by the Diesel engines is of the order of half their nominal power; they reached 3/4 on the 25 km (16 miles) section with the most difficult profile;

e) no actual costs can be given, as these locomotives were designed in 1935, so that they cannot be compared with locomotives built at the present time;

f) the cost of operation per kilometre during 1948 is as follows for these Diesel locomotives:

— maintenance . . . . . .fr.	105.20
— drivers wages	25.87
— fuel	103.69
— lubricants	7.90
— other shed expenses	32.44
Total per km. . .fr.	275.10

g) the costs of repairs are of no value, since these are two prototypes which had to be perfected, and not standard stock.

The average consumption of fuel per kilometre is 4.35 l (0.956 galls. per km or 1.54 galls. per mile);

h) to drive the locomotive the driver has a controller comprising:

— the two levers for starting and stopping the two generators; which are restored to the zero position by spring;

— an acceleration lever regulating the power developed;

— a reversing lever which when removed locks in the zero position the accelerating lever and cuts out all the control circuits.

In addition to the usual gauges, the driver has a board with pilot lights showing if a motor is accidentally overloaded, if the water or oil temperature is excessive, or if the water or oil pressure falls below normal. When one of these lights lights up, a klaxon-horn also blows, which the driver can stop by pressing a button, but the lamp only goes out when the irregularity is corrected. Another button-control makes it possible for the driver to check if the warning-lights are working properly.

If one of the cylinders of the Diesel engine fails, the cylinders still working

are prevented from getting overloaded by inserting, by means of the parts working the injection pumps, a resistance in the excitation circuit of the exciter of the main generator. In this way the Diesel is working at constant injection. This resistance is also controlled by pressure gauges (« manostats ») on the supercharge air pipes and automatically reduces the power required of the Diesel engines if damage occurs to a turbo-blower.

On one of these locomotives, if anything goes wrong with a generating set, the driver is able either to put the corresponding unit out of work (thereby reducing the power at the tread by one half) or to put the group of traction motors corresponding to the electric generator set that is out of order into series with the three other motors by means of a reverser (in which case the power at the tread remains the same, but the speed of the locomotive is reduced by one half);

i) current maintenance operations and periodical inspection take place in the shed while the locomotive is out of work. These operations require about 30 h. work per 1 000 km (620 miles).

Repairs are carried out in the shops. The tyres are re-turned every 220 000 km (136 000 miles); however as the exciters of the generating set of one of the two locomotives are fitted on the bogie axles, the tyres of the wheels of these bogies have to be turned up every 110 000 km (68 000 miles).

The pistons of the Diesel engines have not yet had to be replaced. The sleeves of the Diesel engines of one of the locomotives were replaced in August 1948 after 800 000 km (497 000 miles) owing to corrosion on the outside; those of the other locomotive's engines were still in good order after 750 000 km (466 000 miles). Three of the 8 crankshafts have had to be re-aligned to date.

Danish State Railways.

	Diesel.	*Steam.*
a) Average monthly mileage in kilometres per locomotive	10 000	8 500
Average no. of hours in service per year	4 800	3 000
Average no. of shop hours per year	720	1 440
Average no. of hours examination in the shed per year	445	1 000
Average no. of hours for washing per year	—	480
Average no. of hours in reserve per year (the reserve service includes all the trains)	—	1 050
Average no. of other hours.	2 795	1 790
Total hours per year	8 760	8 760
b) length of mileage in normal working without changing locomotives:		
Average kilometres	135/220	100/200
Maximum kilometres	220/425	200
c) frequency of service breakdowns which led to serious interruptions in the service, per locomotive and per year (from 1-4-48 to 31-3-49)	1.5	0.7

In the case of the Diesel locomotives 70 % of the breakdowns were concerned with the Diesel engine and 30 % with the electrical equipment.

In the case of steam locomotives, the causes of breakdowns can be classified as follows:

— firing (bad fuel) . . . . . 28 %
— injectors . . . . . 15 %
— rods (bearings) . . . . . 15 %
— axle boxes . . . . . 15 %
— fire tubes . . . . . 10 %
— various . . . . . 17 %

d) no trials have been made in this connection, but it can be stated that the

present timetables require the locomotives to work at maximum power;

e) the ratio between the cost price of Diesel locomotives and steam locomotives is about 2.2. : 1.

Interest and sinking fund charges for the two types of traction can be expressed by the ratio 2.7 : 1;

f) operating costs per kilometre at present prices :

	Diesel locomotives		Steam locomotives	
	500 HP	900 HP	500 HP	900 HP
Fuel	25 öre	38 öre	100 öre	120 öre
Lubricants and water	2 »	4 »	3 »	4 »
Maintenance	35 »	50 »	25 »	35 »
Staff	20 »	20 »	35 »	35 »
	82 öre	112 öre	163 öre	194 öre
	(*)			
g) cost of repairs per litre of fuel oil or kilogramme of coal	26 öre	25 öre	2.3 öre	3 öre

(*) Excluding train heating.

h) unlike the steam locomotives, Diesel locomotives only require one man to drive them. There are two levers for regulating the running, one regulating the speed of the Diesel engine (3 phases) and consequently that of the generator and the other regulating the magnetisation of the generator and the field on the traction engines.

Whilst running it is necessary for the driver to keep his foot on a pedal or stud, as otherwise the Diesel engines run light and the automatic brake comes into play;

i) the Diesel engines as well as the electrical equipment, etc., are given a general overhaul every 250 000 to 300 000 km (155 000 to 186 000 miles) (normaly every 3 1/2 years).

Swiss Federal Railways.

a) Average monthly mileage about 5 000 km (3 100 miles) per locomotive; availability about 80 %;

b) maximum run 110 km (68 miles) corresponding to the maximum length of the lines served by Diesel locomotives;

c) damage to the Diesel engine and the battery of accumulators;

d) not established;

e) present cost price about 800 Swiss francs per HP at the tread; fixed annual charges : 6 % of the cost price;

f) operating costs about 1 Swiss franc per kilometre, allocated as between :

Fuel and lubricants . . . . 40 cts/km
Maintenance . . . . . 40 cts/km
Labour . . . . . 20 cts/km

g) cost of repairs about 355 Swiss francs per ton of fuel used;

h) simplicity and safety of running perfectly achieved;

i) mileage between two main overhauls : 250 to 300 000 km (155 000 to 186 000 miles); intermediate overhaul of the Diesel engine after 60 000 to 80 000 km (37 000 to 50 000 miles);

j) fuel consumption :

About 200 g (7.05 oz.) per HP/h. at the tread:

About 10 g (0.35 oz.) per t/km hauled.

Austrian Federal Railways.

Amongst the standard gauge Diesel locomotives, those of 1 000 HP are still under construction and those of 300 HP in service before the war have not been rebuilt. A few narrow gauge (0.76 m = 29.92 in.) units only are in service, so that the economic results obtained by these units only have a limited value.

The data concerning these small locomotives (210 HP) are given below :

Average monthly mileage.	5.000 km
Availability	60 %
Repairs	40 %
Length of run in normal working	65 km
Important breakdowns in service :	damage to motor axles.
Average use of the power	80 %
Total first cost, at present prices	600 000 Sch p. loc.
Total cost price per HP at the tread	4 000 Sch.
Annual sinking fund charges	20 000 Sch.
Operating costs per km :	
fuel	0.70 kg
lubricant	0.01 kg
Repairs :	
shed	0.025 h. p. km
main repair shop . . .	0.05 h. p. km

Simple and safe regulation.

Mileage between two general overhauls : 120 000 km (75 000 milles) for the Diesel engine and electric motors.

Fuel consumption : 1 kg 850 (4 079 lbs.) of fuel per HP per hour.

Portuguese Railway Co.

The 24 Diesel locomotives have only been in service since 1948, so their replies were limited to the following data :

Average monthly mileage :

Diesel locomotive : 122 568 km (76 161 miles) ;

steam locomotive : 284 762 km (176 543 miles).

Average time in minutes saved or lost per month per locomotive :

Diesel : saved, 53; lost, 1 1/2;

steam : saved, 38; lost, 6.

Mileage run per Diesel locomotive :

average : 232 km (144 miles) ;

maximum : 339 km (211 miles).

Simple and safe regulation.

Norwegian State Railways.

Owing to the breaking of the teeth on the driving wheels between the hydraulic converters and the loose-axles (faux-essieux) and because of the difficulty of obtaining spares for the gears, the Diesel locomotive built by Krupp and delivered during 1942 has not been used a great deal. Consequently the only date available concerned the average fuel consumption, which lies between 3 and 5 liters per km (0.66 and 1.1 galls. per km or 1.06 and 1.77 galls. per mile) corresponding to a weight hauled of 300 t.

Belgian National Light Railways.

Owing to the lack of sufficiently complete statistics to enable a complete reply to be given, the following details were supplied :

Average cost of traction (cost of fuel, oil, wages of the engine staff, maintenance, sinking fund charges) on a hilly railway system :

In 1947 : steam locomotives, 30 fr. per km; Diesel locomotive, 13 fr. per km.

Algerian Railways.

a) Average monthly mileage :

1 000 HP (DC) Diesel locomotive : 8 862 km (5 507 miles) in 1948;

1 500 HP (DA and DB) Diesel locomotive : 9 302 km (5 780 miles) in 1948.

A steam locomotive worked about 3 575 km (2 221 miles) in 1938 (normal times) in the same service.

Diesel locomotives :

1 000 HP (DC)	availability	74.5 %	user	50.6 %
1 500 HP (DA and DB)		72.4 %		55.2 %

in 1948.

For information, times saved or lost in minutes in June 1949 by the Diesel locomotives :

	Saved.	*Lost.*
Loc. DC 9 (1 000 HP)	609	0 hauling light passenger trains;
Loc. DB 9 (1 500 HP)	1 052	0 hauling passenger and goods trains;
Loc. DA 9 (1 500 HP)	1 783	0 hauling goods trains;

b) the trains can be hauled without changing the engine. The engine leaves the shed and returns after hauling several trains. The maximum mileage stipulated between departure and return is 930 km (578 miles). The average daily mileage is about 300 km (186 miles);

c) the breakdowns likely to upset the service can be divided up into :

45 % for the electrical part, the greatest damage being the putting out of action of a traction motor or the equipment catching fire (very rare);

55 % for the mechanical part. The breaking of the rods causes the most trouble, but this does not often happen.

Incidents are usually unimportant, and easy to repair, but certain repairs (crankshaft, regulating the bearings and ends of the rods) are rather delicate.

Number of breakdowns with the Diesel : 2.9 per 100 000 km (62 000 miles);

d) the hilly nature of the system and speeds allowed do not enable the engine to be used to the best possible extent, the power only being used up to 100 % on the stiffest gradients;

e) present cost of the 1 000 HP locomotive is $ 137 063, i.e. $ 166.7 per HP at the tread; for the 1 500 HP locomotive the figures are $ 163 560 and $ 130.9 respectively.

Fixed annual charges : $ 9 137 for the 1 000 HP engine and $ 10 904 for the 1 500 HP engine;

f) operating costs (in francs) per kilometre, per unit :

	loco. 1 000 HP	loco. 1 500 HP
Fuel	56	86
Maintenance (staff and materials)	68	77.75
Wages of drivers. . . .	55.80	55.80
Lubricants	4.07	5.03
Other traction costs. .	10.50	10.50
Various	5.—	5.—
	199.37	240.06

g) repair costs per unit of fuel consumed for the two types are respectively 25.6 and 19 fr.;

h) to regulate the engine the driver has :
— a running position lever (F — R and neutral) which works electrically and pneumatically;
— a lever which enables him to regulate the speed of the Diesel engine at the same time, and the excitation field, pneumatically.

The inductor circuit of the main generator is compounded and everything is automatic (EI appreciably constant in the zones of utilisation).

The locomotive is therefore very simple to drive;

i) main repairs are based on the time factor and not mileage. The electrical and mechanical parts are repaired from the front end :

Annual repairs : RI (100 to 110 000 km = 62 000 to 68 000 miles);

General repairs : the period has still to be determined, but it appears that when an engine is due for its annual overhaul, it will have to have a general overhaul;

j) at full load, the 1 500 HP locomotives consume 0.240 (0.052 galls.) and the 1 000 HP 0.272 liters (0.06 galls.) per HP at the tread.

Madagascar Railways.

— average monthly mileage : 6 000 km (3 728 miles) ;
— average and maximum run in normal service without changing locomotive : 255 and 368 km (158 and 229 miles) ;
— serious breakdowns : breaking of the bearings of the traction engines; damage to the turbo-blowers (breakage of the bearings or wings) ;
— variable frequency;
— operating costs per kilometre : about 48.6 fr.;
— mileage between two general overhauls : 200 000 km (124 300 miles) or 10 000 hours (Diesel engine).

QUESTION 4. — *For every type of Diesel locomotive, considering the importance of the type itself, give detailed information about the general characteristics of the locomotive; about the thermal and mechanical characteristics of the motor; about the cooling, starting and power-transmission; about the means and possibilities of the regulation; about the practical performance-characteristics, if possible with diagrams of tractive effort (drawbar pull), power and acceleration; about the quality of the fuel used, and all other information that might be of interest.*

S. N. C. F.

The two Diesel-electric locomotives put into service in 1937 are of two different types : the 262 BD and the 262 AD consisting of twin units permanently coupled together, each consisting of a frame on three driving pairs of wheels and a bogie at each end : 2—Co—2+2—Co—2.

Type 262 BD (fig. 1).

Weight — Mechanical part	109.5
Generating sets :	
Diesel engines t 41.2.	
generators t 16.0	61.2
frame t 4.0	
Diesel auxiliary gear	9.8
battery of accumulators	3.2
traction motors (excluding gears) .	24.6
electrical equipment and cables . .	6.4
fuel, oil, water and sand.	12.1
various	1.2
Total . . t	228.0

The traction motors, with a single armature, are completely suspended and drive the axles by a double set of gears and a quill.

Diesel engines.

— each unit is fitted with a Sulzer supercharged Diesel engine, 4 stroke with mechanical injection, with 12 cylinders 310 × 390 mm (12.2 × 15.3 in.) ;
— speeds : 400-500-600-700 r.p.m.;
— nominal continuous power : 1 900 HP at 600 r.p.m.;
— supercharged power hourly rating : 2 200 at 700 r.p.m.

The supercharging is assured by two Rateau exhaust turbo-blowers; the cooling water is circulated by a 5.5 HP centrifugal motor pump unit.

Electrical equipment.

For each Diesel motor there are :
— 1 10-pole main generator;
— 1 exciter, and
— 3 traction motors with excitation series.

The main generator is self-ventilated, while the ventilation of the traction motors is assured by a 19 HP motor fan. If a generating set is damaged the corresponding unit can be put out of service, or the group of motors corresponding to that set put into series with the three motors of the other unit : the power at the tread remains the same, but the speed is reduced by one half.

The Diesel engine is started up by using a series winding of the main generator which enables it to work in series with current supplied by a Cadmium-Nickel battery. The battery, which has a capacity of 398 Ah. feeds at 120-150 V the drive and control circuits, as well as the air compressors and water circulating pumps. Fans, fuel injection pumps and heating radiators are connected to the auxiliary generators, which also recharge the batteries.

The electrical transmission is on the Jeumont principle.

The speed regulator besides the notch for zero has three notches for starting and 12 for running at constant powers at the tread, scaled from 925 to 3 550 HP.

Three single series windings are fitted on the main generator: 1 series to start the Diesel engine; 1, connected to the battery, exciting the generator when the lever is in the starting notches, through a variable rheostat, and 1, fed by the exciter, coming into play during automatic running. In view of the fact that the exciter, which includes a separate excitation winding and a shunt winding, is driven by a bogie axle, the power required of the Diesel engines remains parctically constant when the speed regulator is kept in one of the notches for automatic running (fig. 2).

Type 262 AD.

The general characteristics being similar to those of the 262 BD locomotive, we shall merely mention the differences. The total weight is 224.5 t.

The traction motors, with two armatures, are entirely suspended and individual axle drive is obtained elastically by a quill driven by a single train of gears.

Whereas the preceeding type has two 1 900 HP sets, the 262 AD has six generating sets; four 950 HP main generating sets and two 130 HP auxiliary ones.

The main Diesel engines are of the M. N. A. fast type with six 300 × 380 mm (11.8 × 15 in.) cylinders:

— nominal continuous power: 950 HP at 700 r.p.m.;

— supercharged power at hourly rating: 1 050 HP at 700 r.p.m.

The auxiliary Diesel engines are of the Saurer B X D type, with six 134 × 180 mm (5.3 × 7 in.) cylinders, and each drives a generator which can develop a continuous power of 105 kW at 1 500 r.p.m. There are four sets of electrical equipment, each identical and separate. Each of the main generators feeds in parallel the three halves of the double traction motors of the corresponding unit, the two armatures of each engine being branched on different generators.

The main generators are 8-pole and self-ventilated; the traction motors, four pole,

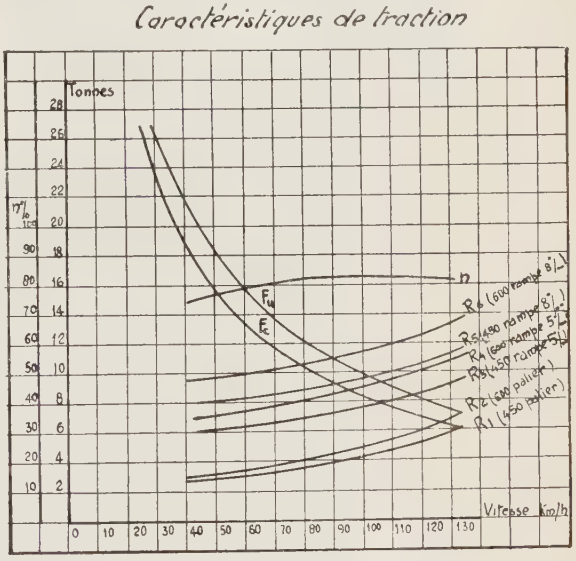


Fig. 1. — 202-BD-1 locomotive. — Characteristics as calculated.

Explanation of French terms :
Caractéristiques de traction = Traction characteristics.

self-ventilated, are of series excitation without reduction of the field.

The Diesel is started by the main generator working in series fed by the battery.

The power supplied by each generating set is regulated by an automatic excitation regulator, on the Cuenod system, controlled by the driving rods of the fuel pumps. If necessary the automatic regulation can be cut out, by working a lever on the controller and the excitation of the exciters regulated by hand.

Safety devices come into play if slipping occurs, or to prevent the reverser being moved into the opposite direction to that in which the locomotive is running.

Danish State Railways.

The Mv type locomotives have a 500 HP Diesel engine directly coupled to a separate generator which supplies current to two motors each of which is suspended on its driving shaft from brackets.

The Mx type has two Diesel engines directly coupled in each case to their respective generator which supplies the current to two driving axles.

specific weight at 20° C : 0.850
point of solidification : -33° C
sulphur : 0.5 %
water, ash, asphalt : 0 %
calorific power : 10 200 cal/kg (40 476.6 B.T.U.).

The Mx type has an automatic steam boiler, with an oil burner. In the Mv type there is a luggage compartment.

Swiss Federal Railways.

The two Diesel electric locomotives are Bo—Bo.

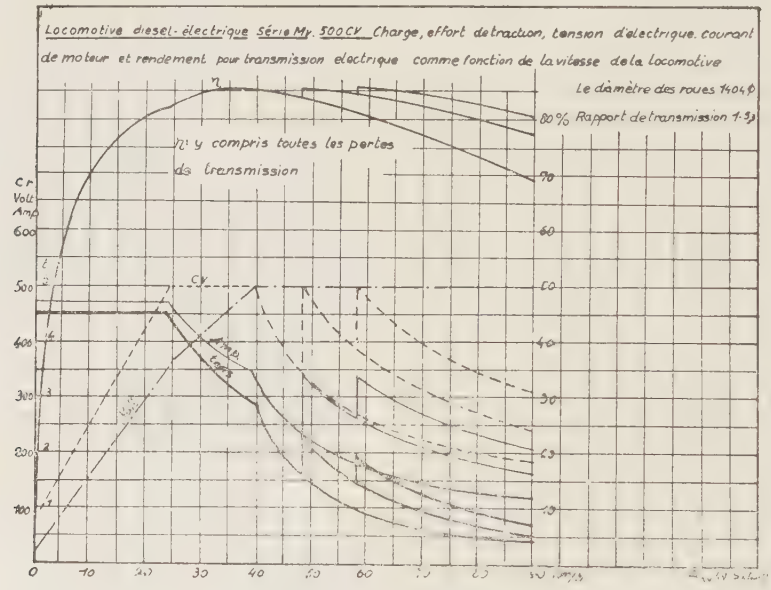


Fig. 2.

Explanation of French terms :

Locomotives Diesel-électriques. Série Mv 500 CV. = Diesel-electric locomotives. Series Mv 500 HP. — Charge, effort de traction, tension électrique, courant de moteur et rendement pour transmission électrique comme fonction de la vitesse de la locomotive. = Load, tractive effort, voltage, current of motor and output for electric transmission as a function of the velocity of the locomotive. — Le diamètre des roues 1404 = Diameter of wheels 1404.— Rapport de transmission 1 : 5.3 = Transmission ratio 1 : 5.3.

The 4 motors are suspended in the same way as the Mv type. The characteristics of the traction and electric transmission of the Mx type are shown in the diagrams (fig. 3 and 4).

The fuel used has the following characteristics :

viscosity at 30° C (82° F) : 1.41 Engler
flash point (PM smoke apparatus) : 75° C

Weight :

mechanical part	26.2
Diesel engine	14.1
electrical equipment (including the batteries as 1.8 t).	20.3
tools, fuel, etc.	4.9
total weight in working order. . . t	65.5

Traction characteristics :

maximum speed : 110 km/h (68 m. p. h.)
tractive effort at driving wheels at hourly rating, 4 370 kg (9 634 lbs.) at 50.60 km/h (31 m. p. h.)
continuous tractive effort at the driving wheels 309 kg (6 812 lbs) at 72.50 km/h (45 m. p. h.)
maximum effort at the tread at starting 10 000 kg (22 046 lbs.)
average tractive effort — at hourly rating 8 000 kg (17 637 lbs.) up to 30 km/h (19 m. p. h.).

Power plant :

4 stroke Sulzer type 86 D A 28 Diesel engines with direct injection, supercharged by turbo-blowers worked by the exhaust gas;

8 cylinders 280 × 360 mm (11 × 14 in.);

Continuous power 1 050 HP at 660 r.p.m. power at hourly rating 1 200 HP at 750 r.p.m.

Running light : 460 r.p.m.

Consumption for 1 050 HP : 165 g/h./HP

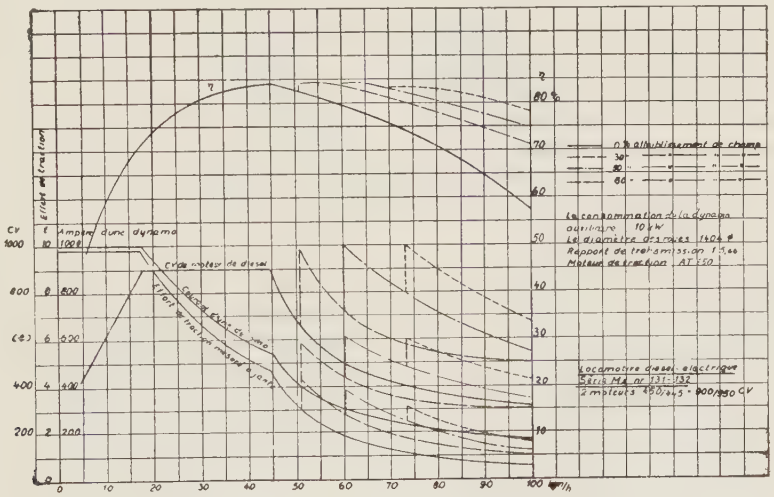

Effort de traction
Ampères d'une dynamo
Courant d'une dynamo auxiliaire 10 kW
Le diamètre des roues 1404 m
Rapport de transmission 17:44
Moteur de traction AT 550
Locomotive diesel électrique
Série Mv nr 131-132
2 moteurs 450/445 - 900/950 CV
km/h

Fig. 3.

Explanation of French terms :

Effort de traction = Tractive effort. — Ampères d'une dynamo = Amperage of one dynamo.— CV de moteur Diesel = HP of Diesel motor. — Effort de traction mesuré à la jante = Tractive effort measured at wheel tread. — Courant d'une dynamo.= Current of one dynamo. — Affaiblissement de champ = Weakening of field.— La consommation de la dynamo auxiliaire = Consumption of auxiliary dynamo. — Le diamètre des roues = Diameter of wheels. — Rapport de transmission = Reduction gearing. — Locomotive Diesel-électrique série Mv nr 131-132, 2 moteurs 450/445-900/950 ch = Diesel-electric locomotive, series Mv No. 131-132, 2 motors of 450/445 — 900/950 HP.

Mechanical part :

The two bogies are identical, and each has two traction motors with elastic quill drive.

The weight is reduced by using light alloys and welding.

The driving compartment and the compartment containing the equipment are separated by partitions.

(5.8 oz. per HP per h.) of fuel and 700 g/h. of lubricants (24.6 oz.).

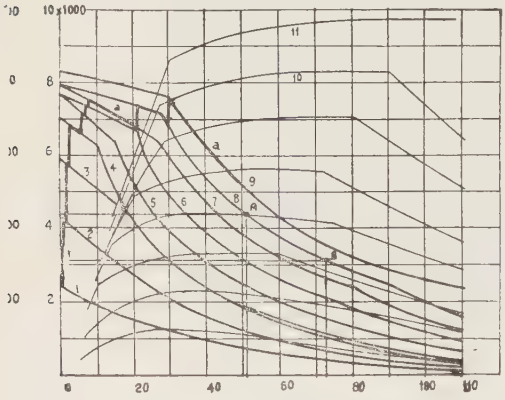
The cooling is by water circulated by an electric pump; a geared pump, driven directly by the crank shaft, keeps the lubricating oil under pressure.

Safety devices stop the engine when the pressure or the temperature of the cooling water or oil reaches a dangerous level.

Electrical equipment :

one A. C. single phase generator to heat the coaches;
1 exciter;
four 4-pole series excitation traction motors, self-ventilated, entirely suspended, with elastic quill drive;
1 battery of accumulators, Ni—Cd, 110 V, 250 Ah, for starting the Diesel engine;
1 auxiliary 36 V group for the lighting circuit;
1 74 kW motor fan;
1 3.4 kW motor pump, to circulate the water;
1 motor compressor for the brake;
1 Brown-Boveri dead-man's handle.

The regulation of the power of the generating set is assured by an excitation regulator controlled by the speed regulator of the Diesel engine. There are 9 speeds of the generating set, corresponding to 9 notches on the speed regulator.



Traction characteristics :
1-9 — Traction curves corresponding to the nine degrees of running.
9*a* — Approximate speed at starting.
10 — Drawbar pull for continuous power of Diesel motor.
11 — Drawbar pull for power output per hour of Diesel motor.
A — Work point for hourly loading of the electric transmission.
B — Work point for continuous loading of the electric transmission.

Fig. 4.

Figure 5 shows the traction and power at the tread of the driving wheels of the locomotive.

Norwegian Railways.

They have a trial prototype delivered by Krupp in 1942, with two M. A. N. engines each developping 1 000 HP at 700 r.p.m., with Buchi supercharging with an individual blower for each engine.

The drive is by means of Krupp hydraulic converters (Lysholm-Smith type); the maximum speed is 100 km/h. (62 miles); the weight in running order is 85 t. The Adhesive weight is 60 t and the fuel carried weight 2 500 kg (5 512 lbs.).

The locomotive and its performance are illustrated in figure 6.

Algerian Railways.

This railways has six types of Diesel locomotives in service; the two oldest are the 4 ADE and 232 ADE built in 1933 and 1939 respectively.

The first has a 4 stroke Sulzer motor with direct injection, 8 cylinders 310 mm × 370 mm (12 × 14.6 in.), power 750 HP at 620 r.p.m., supercharged by a compressor at 1 800 r.p.m.; main generator 560 V; 4 traction engines nose suspended; maximum speed 95 km/h. (59 m.p.h.), tractive effort with shunted field 1 960 kg (4 321 lbs.) at 75 km/h. (47 m.p.h.) at continuous working, and 3 480 kg (7 672 lbs.) at 41 km/h. (26 m.p.h.) at one hour rating.

The second has 2 Sulzer 4-stroke motors with direct injection; 6 cylinders 250 × 320 mm (9.8 × 12.6 in.); maximum power : 1 200 HP at 785 r.p.m., supercharged by turbo-blowers. Rateau exhaust gas blowers; 2 main generators (maximum voltage : 710 V) coupled directly to the motors; 2 auxiliary generators, with continuous tension, mounted on the extremities of the shafts of the main generators; 3 nose suspended traction motors; maximum speed : 120 km/h. (75 m.p.h.); tractive effort : 5 150 kg (11 354 lbs.) at 53 km/h. (33 m.p.h.) in continuous working and 7 000 kg (15 432 lbs.) at 37 km/h. (23 m.p.h.) at one hour rating.

Of the four more recent types, which all have two three axled bogies, the 040 DA is fitted with a 4-stroke Baldwin engine, direct injection, supercharged by Buchi compressor at 10 500 r.p.m.; 8 cylinders in line 324 mm × 394 mm (12.8 in. × 15.6 in.); power 1 500 HP at 625 r.p.m.; Westinghouse electrical equipment, « railway » type main generator (maximum voltage : 750 V), single bearing, one end coupled to the crank shaft; auxiliary generator mounted above the main generator and driven by belt therefrom; 4 traction motors permanently connected in series-parallel, nose suspended and with a gear ratio of 15/63; electro-pneumatic control with automatic device to make sure the Diesel engine is not overloaded; pneumatic regulator; 32 cell acid battery, maximum speed 105 km/h. (66 miles) continuous tractive effort 19 400 kg (42 769 lbs.) at 17 km/h. (11 m.p.h.); at 30 % adhesion, 24 700 kg (54 454 lbs.); weight in running order 125 t; capacity of the fuel tank 3 200 l (704 galls.); weight of the lubricating oil, cooling water and sand 3 000 kg (6 614 lbs.).

The characteristics of the type 040 DB are similar to those of the DA; the main differences are as follows :

— gear ratio 19/64; maximum speed : 132 km/h. (82 miles); continuous tractive effort : 14 000 kg (30 864 lbs.) at 23 km/h. (14 miles), and at 30 % adhesion 25 000 kg (55 116 lbs.).

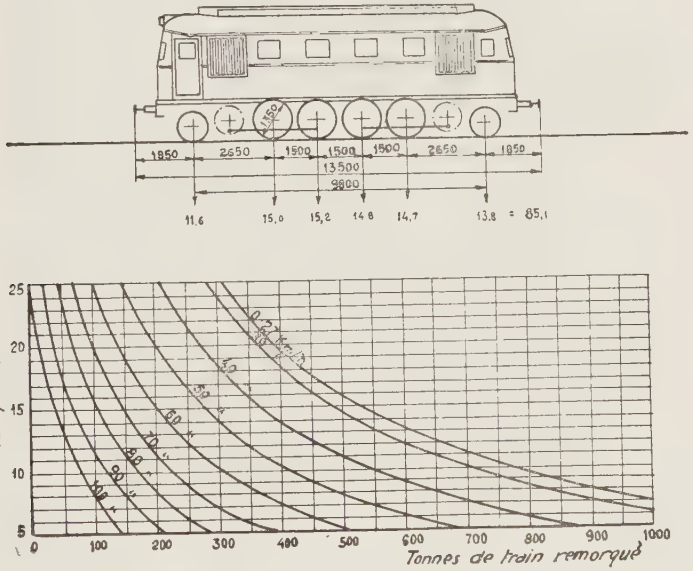


Fig. 5. — 2 000 HP Diesel-hydraulic locomotives.

Explanation of French terms :
Rampe i °/oo = Gradient i °/oo. — Tonnes de train remorqué = Weight in tonnes of rake drawn.

The type 040 D 13 is similarly equipped but the engine is supercharged, with 6 cylinders and 1 000 HP; speed : 96 km/h. (60 miles) and tractive effort : 14 700 kg (32 407 lbs.) at 15 km/h. (9 m.p.h.) and 22 800 kg (50 266 lbs.) at 30 % adhesion; the weight in running order is 103 t.

The type 040 DD whose weight in working order is 107 t has an Alco 4 stroke

compression ignition engine, supercharged with 12 cylinders 229 mm × 267 mm (9 in. × 10.5 in.); G. E. electrical equipment; maximum speed : 120 km/h. (75 miles); tractive effort : 17 000 kg (37 478 lbs.) at 20 km/h. (12 miles) in continuous working and 21 000 kg (46 297 lbs.) at 30 % adhesion.

Of the locomotives described above, the DA and DB are twin units which may be driven by a single man. The DC and DO are multiple units which may also be driven by one man.

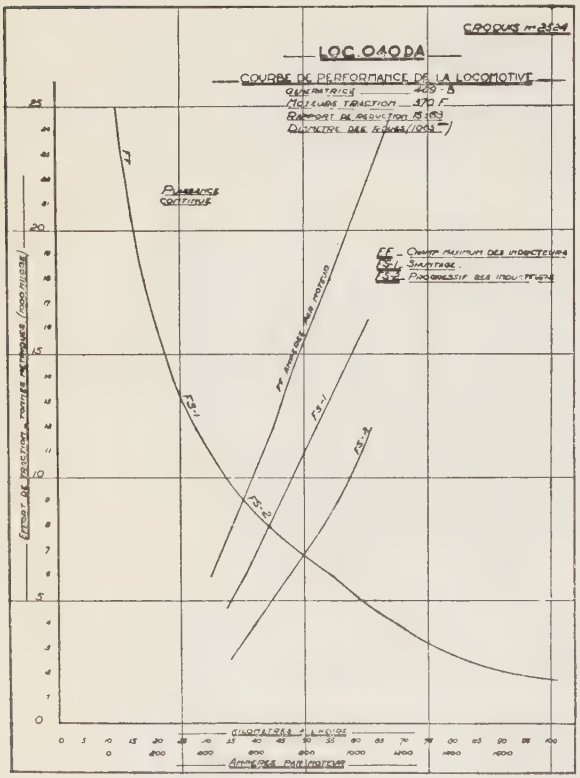


Fig. 6.

Explanation of French terms :

Courbe de performance de la locomotive = Performance curve of locomotive. — Génératrice = Generator. — Moteur de traction = Traction motor. — Rapport de réduction = Reduction gearing. — Diamètre des roues = Diameter of wheels. — Champ maximum des inducteurs = Maximum field of inductors. — Progressif des inducteurs = Progressive of inductors. — Puissance continue = Continuous power.

Figures 7 and 8 give curves showing the traction characteristics of the 040 DA and DB locomotives.

Gafsa Railways.

The locomotives are built by the Alsthom Company; they are mounted on two bogies with 2 driving axles :

1 Sulzer engine type LDA 25 supercharged, with 6 cylinders in line, 250 mm × 320 mm (9.8 × 12.6 in.), the power being :

at peak load working 625 HP at 850 r.p.m.;

at continuous load 560 HP at 795 r.p.m.;

1 main generator 400 V D. C. 780 A at 795 r.p.m.;

1 auxiliary generator 60 kW D. C.;

four 400 V traction motors — 195 A at 450 or 840 r.p.m. according to the field.

Weight of the power plant : approx. 10 t;

Weight of the electrical part : approx. 14 t;

Weight of the mechanical part : approx. 22 t;

Total weight in working order : 51 t.

The total tractive effort at the tread (continuous working) is 7 600 kg (16 755 lbs.) with maximum field, and 4 080 kg (8 995 lbs.) with reduced field. The maximum effort at the tread on starting is 14 000 kg (30 864 lbs.). Maximum running speed 70 km/h. (43 miles).

Madagascar Railways.

Three bogie locomotives, with 2 driving axles apiece are used. The single frame has a driving compartment at each end, and rests on each bogie by a spherical pivot and two lateral equalisers; the pivot rests on a centre plate which can move transversely. Each locomotive has a generating set consisting of a supercharged Diesel engine driving on the same shaft :

A variable tension main generator from 0 to 750 V feeding the three traction motors connected in parallel;

An auxiliary generator at more or less

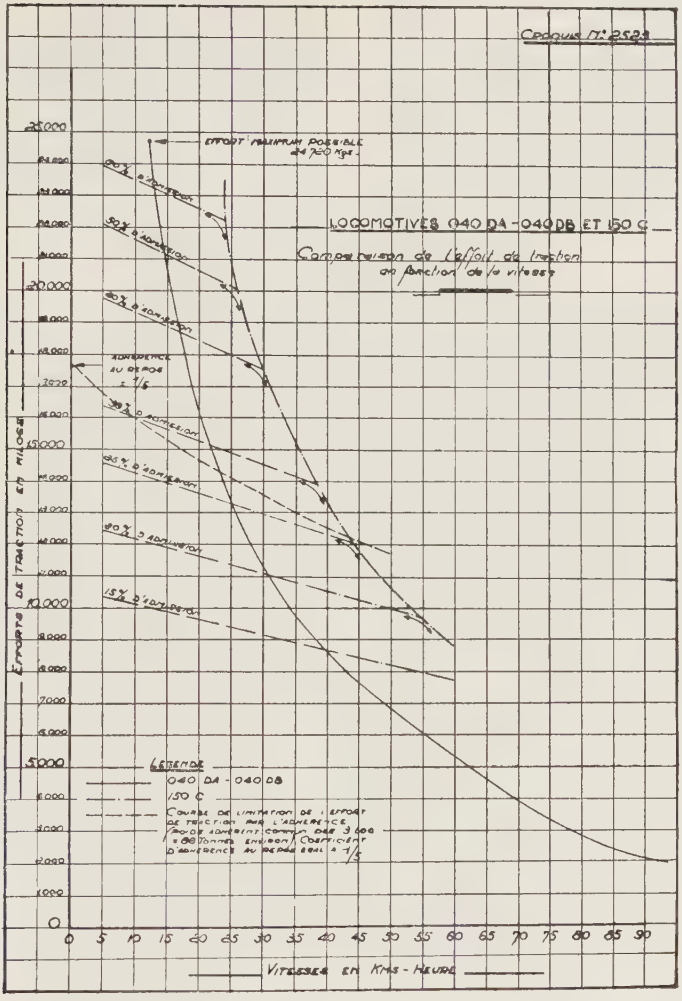

Croquis N° 2523
LOCOMOTIVES 040 DA - 040 DB ET 150 C
Comparaison de l'effort de traction en fonction de la vitesse
EFFORT TRACTIF POSSIBLE de 7750 kgs.
90 % d'adhérence
80 % d'adhérence
70 % d'adhérence
ADHERENCE AU DEPOS = 1/6
60 % d'adhérence
50 % d'adhérence
40 % d'adhérence
15 % d'adhérence
EFFORTS DE TRACTION EN KILOGS
LEGENDE
040 DA - 040 DB
150 C
Courbe de limitation de l'effort de traction par l'adhérence
Poids adhérent commun des 3 loc. de 88 tonnes environ. Coefficient d'adhérence au repos égal à 1/6
VITESSES EN KMS - HEURE

Fig. 7.

Explanation of French terms :

Comparaison de l'effort de traction en fonction de la vitesse = Comparison of the traction effort as a function of velocity — Courbe de limitation de l'effort de traction par l'adhérence = Curve of tractive effort as limited by adherence. — Poids adhérent commun des 3 loc. de 88 tonnes environ = Common adhering weight of the 3 locos, approx. 88 tonnes. — Coefficient d'adhérence au repos = Coefficient of adherence at rest.

constant voltage equal to 155 V for the speed notches 790 and 700 r.p.m. feeding the electric circuits;

An exciter at variable voltage feeding a special separate winding on the traction motors in order to over-excite them on starting and provide automatic progressive shunting as the speed of the locomotive increases.

The 6 traction motors drive the 6 axles

individually by straight gears. The two motors of each bogie are cooled by the same power driven fan fitted under the bolster of this bogie.

Automatic regulation of the power is assured by the Als-Thoms-Royer system characterised essentially by the use of a circuit, separated from the main generator, the appropriate regulating resistance.

The equipment makes it possible to run as a multiple unit two locomotives coupled together.

The traction characteristics are shown in the diagrams (figs. 8 and 9).

MADAGASCAR

Diesel electric locomotive. — Type BBB, 625 HP

Traction characteristics :

Continuous power of Diesel motor	625 HP
Average power absorbed by auxiliary apparatus	45 HP
Continuous power available for traction	580 HP

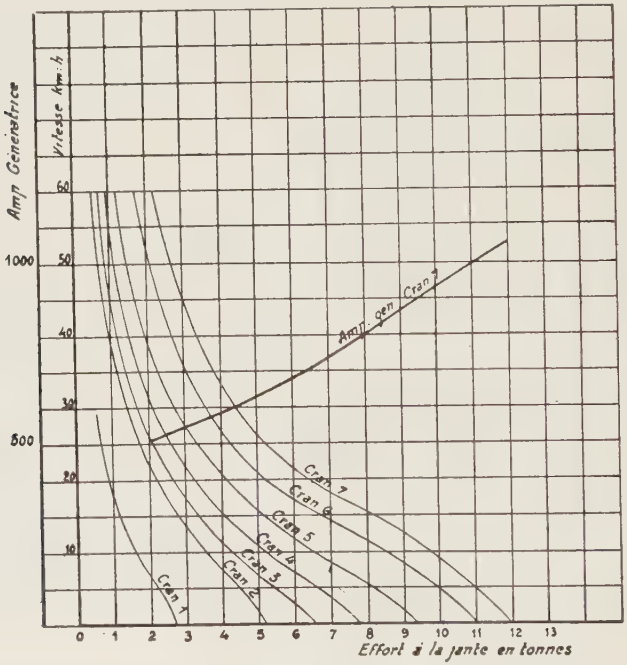


Fig. 8.

Explanation of French terms :

Amp. génératrice = Amps of generator. — Effort à la jante en tonnes = Effort at wheel tread in tonnes.

main generator with three excitation windings. This is combined with a Sulzer device working the automatic rheostat controlled by the speed regulator and introducing at each instant into the excitation

QUESTION 5. — *Which power-units do you use to-day, and which are you planning to use in the years to come? Which are the corresponding weights, empty and in working order?*

QUESTION 6. — *When you need high power, do you prefer either high-powered single-units, or coupled units of limited power, and why?*

QUESTION 7. — *For which type of train-working do you consider the replacing of a steam-locomotive by a Diesel-locomotive preferable?*

QUESTION 9. — *How is the outlook, on your system, for the further development of Diesel traction in the near future?*

The replies to questions 5 to 9 often repeated the same information at great length; we have taken them together for the sake of brevity.

MADAGASCAR

Traction motor TA 612A

Characteristics at 600 V. — Wheel 900 mm. — Reduction 6.06.

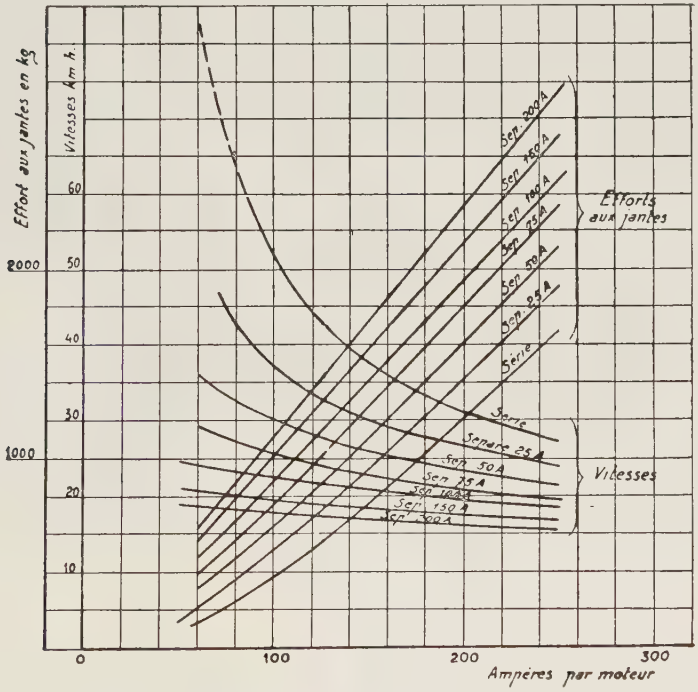


Fig. 9.

Explanation of French terms : Effort aux jantes = Effort at wheel treads.

QUESTION 8. — *Do you have special facilities for maintenance and servicing, cleaning included, for Diesel locomotives in your depots? If so, please give details, if possible with drawings and photographs.*

S. N. C. F.

Owing to the electrification programme for the main lines and the number of the steam locomotives thus made available, the S. N. C. F. is not considering extending its use of powerful Diesel locomotives on the

main lines; they are keeping this method of traction for the railcars, shunting in the yards, and hauling goods trains of average tonnage on lines where this will make it possible to do away entirely with steam sheds. As a result of this policy, the S. N. C. F. has not had any need to build sheds exclusively for the garaging and maintenance of Diesel train locomotives in the case of light passenger trains, but they are of the opinion that development in the future is likely to be in the direction of very powerful units, with electrical equipment of large dimensions, supercharged Diesel engines, automatic regulation and automatic steam boilers.

For the maintenance of the Diesel locomotives, but in some of the steam sheds there is recently installed equipment designed for the maintenance of the different types of Diesel locomotives (shunting, etc.) (fig. 10).

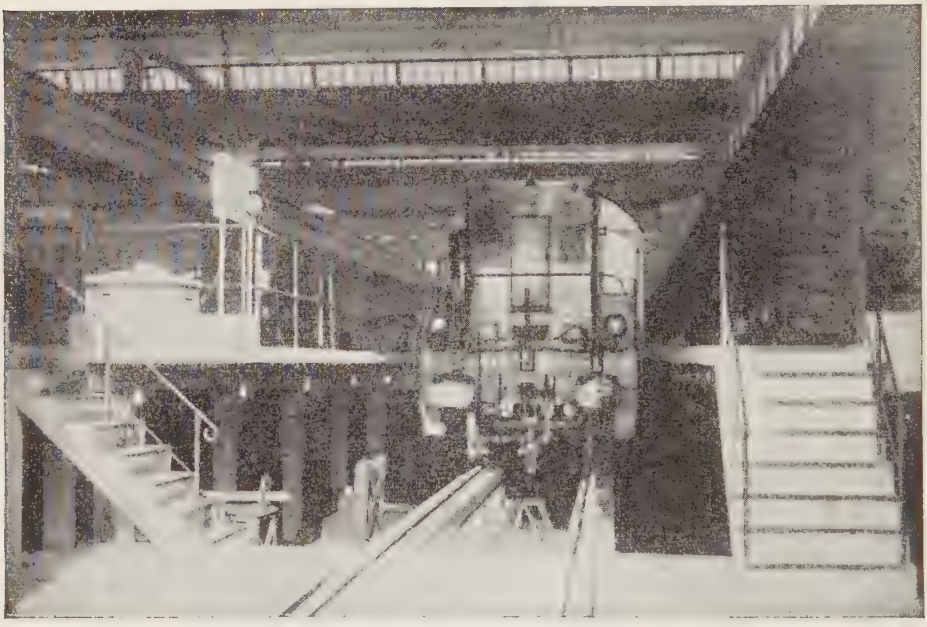


Fig. 10. — Depot at Villeneuve Saint-Georges. — Diesel workshop. — Details of the different working levels, lighting of the lower level and of the pit.

Danish State Railways.

The problem of the power to be used and its distribution in the coming years is at present under investigation. The Danish Railways consider it preferable to substitute Diesel locomotives for steam locomotives at the present time, there are inspection pits, compressed air equipment, lubricant filters, pumps for supplying fuel and lubricants, portable containers for changing the accumulators of the charging resistances and a machine for grinding the valves.

Swiss Federal Railways.

The C. F. F. are in favour of a maximum power of about 1 500 HP and owing to the complete electrification of their system,

only foresee a limited development of Diesel locomotives, their use being limited to shunting and breakdown services.

Austrian Federal Railways.

Their reply shows that they prefer high powers, the use of separate units of about 1 000 HP which can be coupled together, as this makes it possible to standardise the parts and gives greater flexibility of operation. The locomotives will preferably be used for passenger trains and light goods trains on the main lines.

The Portuguese Railway Company is not yet able to reply to these questions. They are studying the construction of special installations for the maintenance of Diesel locomotives.

On the Swedish State Railways the question of using Diesel locomotives for the train services is under study. At the present time there is no need for horse powers exceeding 800 in the case of narrow gauge lines and 1 200 to 1 600 for the standard gauge lines. The steam locomotives will be replaced by Diesel locomotives for all the different services on lines which it is not possible or convenient to electrify. Steam locomotives will probably be replaced by Diesel locomotives if sufficiently powerful units can obtained whilst keeping the axle loads relatively low.

The Norwegian State Railways are electrifying their main lines and consequently substituting electric locomotives for steam locomotives.

However they have carried ou trials with a 2 000 HP Diesel locomotive to be used on the Bergen line, where there are a great many tunnels, and it will be advantageous for giving high speeds on the long, steep gradients, using two units in the mountainous section. For this reason the locomotive is equipped with remote control.

The Belgian Light Railways, whose bridges were built for a maximum axle load of 10 t, are using 160 HP Diesel tractors whose weight in running order is 19 t (2 axles), but they have under construction a 30 t bogie tractor of 300 HP.

They are not considering coupling these Diesel tractors together.

Except in the case of some exceptionally heavy services or for seasonal services, for which 23 t steam locomotives of the Garatt 40 t type are used, all the other steam locomotives will be replaced by Diesel tractors.

These tractors are maintained and repaired in the same shops and sheds as the Diesel railcars, and this stock will meet the requirements of the goods services and heavy passenger services on the non-electrified lines.

The Algerian Railways are using 1 000 HP Diesel locomotives for light trains on lines where heavier axle loads cannot be allowed, and 1 500 HP locomotives for the main line trains. They are not considering using higher powers.

In general they are of the opinion that if great powers are regularly needed, there would be advantage in possessing a number of traction engines adapted to these requirements; on condition that the limiting strength of the couplings is not an obstacle and the weight per axle is acceptable to the Permanent Way Department. The number of locomotives in service would be decreased and the costs lower, for, in fact, the maintenance costs for a powerful Diesel are not much higher than those for a similar locomotive of the same make but of lesser power. The number of drivers required will also be less.

On the other hand it is difficult to regulate the multiple units in such a way that the same running conditions apply on each unit.

If very powerful locomotives are only required occasionally, it is better to obtain the necessary power by coupling up units rather than to have to strengthen the track and buy powerful and consequently heavy locomotives whose dead weight will be excessive when their power is not used to the full.

On the Algerian lines there are special installations for maintenance (illustrated in figs. 13 and 14), but not for cleaning.

The replacement of the steam locomotives by Diesel locomotives is considered advantageous for all the services, since it is not possible to electrify the lines, there is no coal mine in the country and water for steam is of poor quality. Steam traction will consequently be replaced by Diesel traction as credits become available. Normally this should be achieved by the end of 1950.

No Diesel locomotive properly speaking has yet been built for the narrow gauge lines.

The Gafsa Railway is considering the use of double-unit Diesel-electric locomotives. Units of average power are preferred to very powerful units because the track, which is metre gauge with 25 kg (55 lbs.) rails, cannot stand up to heavy axle loads, and on various sections of the system light trains only can be run, for which a single unit will suffice.

The Madagascar Railways prefer units which can be coupled together for the following reasons :

— better use of the traction stock which can always be used at full load, even if there are considerable daily variations in the traffic;

— there are many curves and double curves of a minimum radius of 50 m (164 ft.); when the train is a certain length, the second locomotive can be placed in the middle. There are no special installations for the maintenance of Diesel locomotives.

Diesel traction is considered useful for

Fig. 11. — Special maintenance equipment for Diesel-electric locomotives.

the heavy train services, or speeded up services, both passenger and goods, and it is intended to order 8 other locomotives, which will bring the stock of Diesels to 20 units. Light passenger trains and speeded up trains will be hauled by motor vans.

The Franco-Ethiopian Railway has not yet got any Diesel locomotives in service, but they have 12 on order. Units that can be coupled up have been selected because this will facilitate running through curves, and also make maintenance very much easier.

Special installations for the maintenance of these Diesel locomotives are under consideration. Diesel traction is considered preferable for all the services, and if the results obtained prove satisfactory, will gradually replace steam traction entirely.

Considerations.

The reports of the different Administrations show that Diesel traction is considered from very differing points of view.

Many African and Colonial Railways, where steam traction is handicapped by difficulties as regards quantity and quality of water, the high cost of coal delivered to the place of consumption, the low average speeds obtainable, by an unduly low average coefficient of utilisation of locomotives, and by the other well known disadvantages linked up therewith, find it essential to have a method of traction which is more powerful and independent, better adapted for long runs and amply able to provide on its own an elastic and sufficiently fast service, even on lines of light construction with many small radius curves. As electrification is generally out of the question, either for practical reasons or on account of the amount of traffic, Diesel traction finds itself in a very strong position.

A tendency in this direction is already noticeable, and consequently it appears likely that in such countries Diesel traction will ultimately replace steam traction completely within a very short period.

As regards the European Railways, the question arises in a different way, and there is less unity of purpose. Railways which already have extensive electrification or which are planning to develop this method of traction, look upon the Diesel locomotive as suitable for secondary lines (on which electrification would not be a paying proposition) and for emergency services. On the other hand, in countries producing coal and not oil, the use of the latter on a large scale instead of coal on the railways would come up against obstacles from the point of view of national economy, as well as social and military considerations, and it is likely that in time such railways will tend towards the gas turbine using pulverised coal, although this would not preclude a moderate development of traction by Diesel locomotives in certain special cases, and to second the evolution of industrial technique for export ends.

In other countries, where the above mentioned considerations are not of so great moment, Diesel train locomotives are of great interest and will, in some cases, be used even on important lines.

The Diesel locomotive has a higher coefficient of utilisation, better regenerative possibilities, and, even though incidents may occur rather more frequently, very satisfactory regularity in service and a user which may reach a figure of 250 000 ÷ 300 000 km (155 000 to 186 000 miles) between two general repairs.

All the Diesel motors are four stroke with direct injection, running at 600 to 700 r.p.m. and supercharged, the latter often being achieved on the European designs by using the exhaust gases.

In nearly every case, the transmission is electrical with automatic power control; this makes the locomotive safe and easy to drive, thereby justifying the use of only one man.

The traction motors are generally sited

one on each axle, with nose suspension (especially in the American designs) or with quill drive.

The principle of dividing up the power amongst one or several Diesel motors varies considerably; we find locomotives with a single motor for powers from a few hundred up to 1 500 HP, with two motors for powers ranging between 900 and 3 800 HP, and finally with four motors for a total of 3 800 HP.

The Power-rating considered to be the most appropriate for each locomotive is 600 ÷ 800 HP on narrow gauge lines and 1 000 ÷ 1 500 HP on standard gauge lines, it being possible to couple these locomotive together. Regarding this latter point there is unanimity of opinion on the advantages to be obtained from standardising the parts, as regards flexibility of operation, easier inscription through curves, etc.

The weight in running order per unit of power provided differs appreciably with the different types; in the American types considered (1 000 ÷ 1 500 HP) 80 ÷ 100 kg (176 to 220 lbs.) per HP, it is approximately the same as for the standard steam locomotives with tender, of equal power. This may prove a serious difficulty when using them on secondary lines which are not strong enough to take heavy axle loads. Some of the European designs mentioned in this report show that this weight can be kept within the limits of 60 to 70 kg (132 to 154 lbs.) per HP and a still further reduction may be looked for in view of the rapid and uninterrupted evolution of the technique, especially if such a reduction should prove to be of absolute necessity.

Hydraulic drive, which has mostly been abandoned in favour of electrical transmission, allows a large reduction in weight, and may be a solution in particularly difficult cases.

The replies give the impression, even when this is not expressly stated, that many of the Administrations covered by the present report are tending to give up building new steam locomotives, either for the train services or for shunting.

The period of decline of the traditional steam locomotive appears therefore to have begun, but it cannot yet be looked upon as out of date; almost everywhere it will still be able to render very useful service, in view of the numerous units in operation, and in some countries its technical evolution can be caried still further and new designs brought out.

However that may be, the characteristics which the European Railways consider as being favourable for Diesel traction are in the main economic in character (lower operating costs) although they do not overlook its possibilities in connection with providing faster and more flexible services (particularly on secondary lines) and ensuring greater comfort owing to the elimination of smoke.

It is a well known fact that the Diesel locomotive has nearly four times the total output of the corresponding steam locomotive, but its advantage from the point of view of operating costs must be put at a much lower figure.

Only the Danish State Railways gave comparative data, the other Administrations supplying figures relating to Diesel traction only.

Consequently it is impossible to give a sufficiently accurate comparative table.

Although in the United States of America the saving in favour of Diesel locomotives is taken as being of the order of 15 % on fuel costs alone, and 30 to 40 % for the total operating and maintenance costs, according to the replies received to the questionnaire it would appear that in the European countries the saving on maintenance, staff and other costs is not out of the way, and the saving on fuel costs depends entirely on local conditions and the state of the market. For example the Danish State Railways give such ratios as 1 : 3 ÷ 4 for the latter costs for Diesel and steam locomotives, whilst on the

S. N. C. F. and C. F. F. the price of fuel does not appear to leave a very wide margin.

On the other hand the purchase price of Diesel locomotives is very high, and generally more than double that of steam locomotives, which implies that the figures for interest and amortisation (which covers a shorter period) are proportionately higher, so that more capital is involved, which is a very serious matter in the case of a large scale replacement programme.

Nor can the fact be overlooked that the way is not barred to further improvements in the steam locomotive, such as for example a new method of preheating by the exhaust gases, now coming to the fore, which when applied to existing units will give an appreciable increase in power, and considerable savings in fuel consumption.

Considerations stressing the remarkable advantages in favour of Diesel traction are no doubt convincing from the general point of view, but do not always warrant priority in every case.

The future therefore is likely to provide large possibilities of development for the Diesel locomotive, but with a certain lack of geographical unity, i.e. it will be almost complete in some countries, parallel with the development of steam traction in others, and on a very reduced scale in places where special operating characteristics and the availability of current make electrification the preferable solution.

B. — Shunting locomotives.

QUESTION 1. — *Do you use Diesel locomotives for shunting (switching) purposes in your freight-yards and big stations? Do you also use small locomotives or tractors with Diesel power for shunting (switching) in average and small stations? To what extent, and since when?*

We give below the actual situation as regards the use of Diesel traction for shunting on the railways who supplied details :

French National Railways (S. N. C. F.) — Has 106 Diesel locomotives and 257 locotractors. (In this report locotractor designates engines, generally four wheeled, whose power does not exceed 200 HP.) Its programme covers an increase in this stock, as no further steam shunting engines will be built.

Danish State Railways. — Employ 25 tractors and 1 Diesel-hydraulic locomotive.

Austrian Federal Railways. — Have a small number of locotractors in service and 20 Diesel locomotives under construction.

Italian State Railways (F. S.). — Have 49 Diesel-electric locomotives and 186 locotractors. The locomotives were put into service after the war, while the locotractors were first tried in 1931.

Portuguese Railway Company. — Has had 12 Diesel-electric locomotives and 6 Diesel tractors in service for one year.

Swedish State Railways. — Have several tractors with internal combustion and Diesel engines in service and a new type of Diesel tractor on order. In addition two Diesel-electric locomotives have been undergoing trials for the last six months.

Belgian National Railways Company. — Use 4 Diesel-electric locomotives and 1 Diesel-hydraulic locomotive.

Netherlands Railways. — Have had 45 Diesel-electric locomotives in service since 1946 and 20 locotractors since 1934.

Luxemburg National Railways Company. — Has 3 Diesel tractors.

Algerian Railways. — Have 12 Diesel-electric locomotives put into service in 1948, and 23 locotractors, 5 for 1.055 m (3 ft. 5.5 in.) gauge lines, which have been in service since 1930.

Lower Congo to Katanga Railway Company. — Put 2 Diesel locomotives into service two months ago.

Finally, the *Norwegian State Railways, Paris Transport Board, Colonial Transport Office (Otraco)* and *Gafsa Railways,* none of which have any Diesels in service for shunting at the present time (the Norwegian State Railways use petrol engined tractors) have locomotives and locotractors on order which they intend to put into service very shortly.

QUESTION 2. — *For every type, and considering its importance, please give detailed information about the general characteristics; the motors and the auxiliary outfit; the power-transmission; the regulation; the practical performance characteristics; the eventual troubles or difficulties met in use, and all other information you may think of interest.*

Amongst the numerous types of locomotives and locotractors about which details were given, the following appear to be of interest as having characteristics which have attained their final development.

S. N. C. F.

Will complete in a few months the series of three classes of locotractors and three classes of shunting engines with 3 to 4 axles.

Locotractors.

Class 1 : small units of 8 ÷ 10 t, 25 ÷ 30 HP intended to shunt wagons and locomotives in the sheds.

Class 2 : 16 ÷ 20 t locotractors, 50 ÷ 60 HP used in the large sheds and shops and average sized yards. Drawbar HP 2 000 kg (4 409 lbs.) at a speed of 4.5 km/h. (2.8 m.p.h.) and 550 kg (1 213 lbs.) at 15 km/h. (9 m.p.h.); maximum speed 50 km/h. (31 miles).

Class 3 : 32 t locotractors, 135 ÷ 150 HP can haul 600 t on the level; maximum speed 60 km/h. (37 miles).

Although the drive on all these locotractors is of the electrical type at the present time, it is expected to have mechanical drive in future to decrease the cost price.

Locomotives.

Class 1 : weight 51 ÷ 54 t; power 360 ÷ 380 HP hydromechanical drive : two prototypes will shortly be put into service.

Class 2 : weight 51 ÷ 54 t; power 500 HP. Electrical transmission. 48 units are under construction and will soon be put into service. The locomotives can be coupled together in pairs, or to a 6 wheeled truck tractor, carrying additional fuel oil, the electrical motors of which are connected to the locomotive generator, in series with those of the locomotive. In this way a unit of great adhesive weight will become available which will be able to carry out shunting operations in the large marshalling yards, especially the shunting of 1 800 t trains.

Class 3 : 100 American Diesel locomotives put into service in 1946 belong to this class. They are used for most of the heavy shunting operations, their characteristics being :

Designation : A — 1 — A + A — 1 — A
Weight in running order : 109 tonnes.
Adhesive weight : 72 tonnes.
Capacity of fuel tank : 3 220 litres (708 galls).
Westinghouse direct and automatic air brake.
1 « Baldwin » 4 stroke compression ignition engine, not supercharged, with mechanical injection.
6 cylinders in line : 323.85 mm + 393.7 mm (12.75 × 15.5 in.).
Nominal power and speed : 750 HP at 625 r. p. m.
Idling speed : 312 r. p. m.
Fuel supplied by a geared pump driven electrically; lubrication by geared pump driven by the Diesel engine; cooling by water circulated by a pump driven by the Diesel engine; fans for the oil and water radiators also driven by the Diesel.

The electrical equipment consists of :

1 main generator self ventilated.
1 auxiliary generating set — exciter;
4 series excitation traction motors, nose suspended, ventilated by means of fan driven mechanically by the C. I. engine.

The Diesel engine is started by the main generator working as a series motor and fed by the batteries.

The acceleration is controlled pneumatically; the automatic regulation of the power is obtained by feeding the field of the main generator by two windings, one independent and the other anticompound.

The traction efforts at different speeds are given below :

speed (km/h)	10	20	30
effort at the tread (kg)	13 000	7 100	4 800
speed (km/h)	40	50	60
effort at the tread (kg)	3 500	2 800	2 300
speed (km/h)	70	80	90
effort at the tread (kg)	1 800	1 400	1 100

The maximum effort at the tread at 30 % adhesion is 21 200 kg (46 738 lbs.); the maximum speed is 96 km/h. (60 miles).

The S. N. C. F. point out that the type of drive to be used on the locomotives of this class yet to be built has not been decided upon, and will depend upon the results obtained with the prototypes of the locomotives of class 1.

Italian State Railways (F. S.).

The 49 Diesel-electric locomotives belonging to the Italian State Railways were bought from the American military authorities. Their characteristics are summed up in the table below :

Designation : Bo+Bo.

Total weight : 59 t.

Capacity of fuel tanks : 1 514 or 3 933 litres (333 or 865 galls.) according to type.

Maximum speed : 74 km/h. (46 miles).

The thermal equipment consists of two 4 stroke Diesel engines with mechanical injection, supercharged :

— 6 cylinders 171.45 mm × 222.25 mm (6.75 × 8.75 in.);

— maximum nominal power at 1 200 r.p.m., 325 HP;

— idling speed : 400 r.p.m.

The fuel is supplied by a piston-type pump worked by the Diesel engine; the pumps for the oil lubrication under pressure and for circulating the cooling water are also driven by the Diesel engine.

Each C. I. engine has corresponding to it :

— 1 main generator;

— 1 exciter;

— 2 traction motors with series excitation, nose suspended.

The Diesel engine is started, according to the type of locomotive, by a starting motor fed from the batteries or by the main generator working as a motor in series, fed from the batteries.

The traction motors can be coupled in series or in parallel.

Figure 12 gives a speed-tractive effort diagram for these locomotives.

The regulation of the power supplied by the generating set is obtained automatically as the exciter has three field windings, one of which is fed by the batteries, the other in derivation on the exciter itself, and the third in series on the circuit of the main generator in opposition to the independent field. The exciter in turn feeds the field of the main generator.

These locomotives are used above all for shunting operations in the large marshalling yards and stations.

For shunting operations the Italian State Railways have at the present time : 114 locotractors; weight in running order 6.5 t; power 65 HP. Maximum speed 25 km/h. (16 miles) and 72 locotractors : 12 t, 105 HP, 41.50 km/h. (25 miles) maximum speed. The general characteristics of these two types are very similar :

— high speed 4 stroke Diesel engine, mechanical drive, the motor is started by means of a small starter motor.

The two types of locotractors are fitted with a device to increase the adhesive weight, by using part of the weight of the next wagon.

These units are intended to shunt wagons in the shops and carry out shunting operations in small and average sized stations. At the present time trials are in hand to use 105 HP locotractors for pulling light goods trains on secondary lines.

1 200 locomotives

Performance curve for the 295 HP absorbed by each of the two main generators.

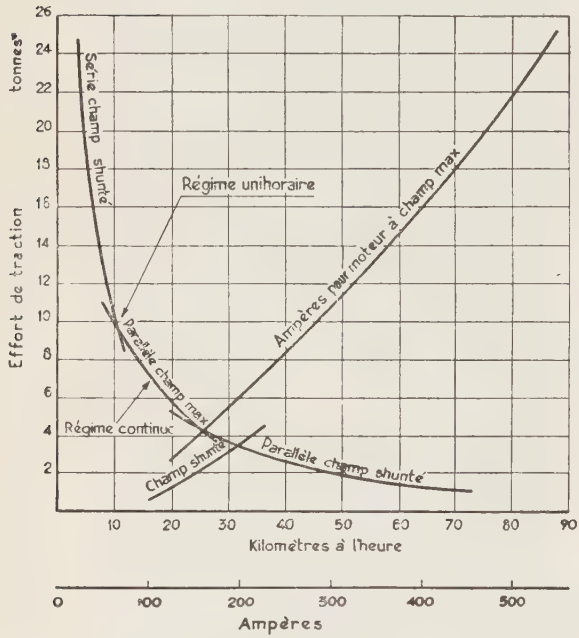


Fig. 12.

Explanation of French terms :

Efforts de traction-tonnes = Tractive effort-tonnes. — Ampères pour moteur à champ max. = Amperes for motor with maximum field. — Champ shunté = Shunted field. — Régime continu = Continuous rating. — Régime unihoraire = Hourly rating.

Netherlands Railways.

The shunting engines used by the Netherlands Railways can be divided into 3 classes :

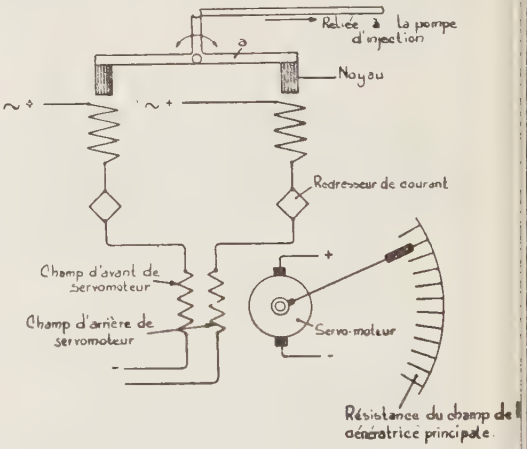
Class 1 : designation Bo, power 250 HP, weight 37 t; one 4 stroke Diesel engine, 6 cylinders 195 mm × 260 mm (7.7 × 10 in.); electrical transmission from a main generator, 1 exciter, 1 auxiliary generator, 2 self-ventilated traction motors with series excitation.

The regulation of the power is obtained by acting on the field resistance of the main generator linked up with the injection pump as shown diagrammatically in figure 13. The principle of this arrangement is the changing of the resistance of the winding of the alternating current by the introduction of the core more or less deeply in the winding. These windings are connected by current rectifiers to the front and back field of the servomotor.

Figure 14 gives performance curves of the class 2 locotractors, designation C, weight 52 t, power 355 HP at 680 r.p.m.; one 4 stroke Diesel engine, 6 cylinders 254 mm × 305 mm (10 × 12 in.); electrical transmission by means of a main

Netherlands Railways.

Diesel-electric Shunting locomotives.



Regulation of the field of the main generator.

Series 400 locomotive.

Fig. 13

Explanation of French terms :

Reliée à la pompe d'injection = Connected to injector pump. — Noyau = Core. — Redresseur de courant = Current rectifier. — Champ avant de servomoteur = Front field of servomotor. — Champ arrière de servomotor = Rear field of servomotor. — Resistance du champ de la génératrice principale. = Resistance of field of main generator.

generator which feeds two traction motors. There is a separate motor for starting up the engine. The locomotive is also fitted with a generator for the lighting and an auxiliary generator. The power is regulated by electrical communication between the throttle and the field of the main generator.

Class 3: designation Bo + Bo; weight 59 t, maximum speed 75 km/h. (47 miles), two 287 HP Diesel engines at 1 200 r.p.m. each.

The general characteristics of the heat engines and the electrical equipment of these locomotives is similar to that of the Italian State Railways Diesel-electric locomotives already described.

The *Netherlands Railways* also have a

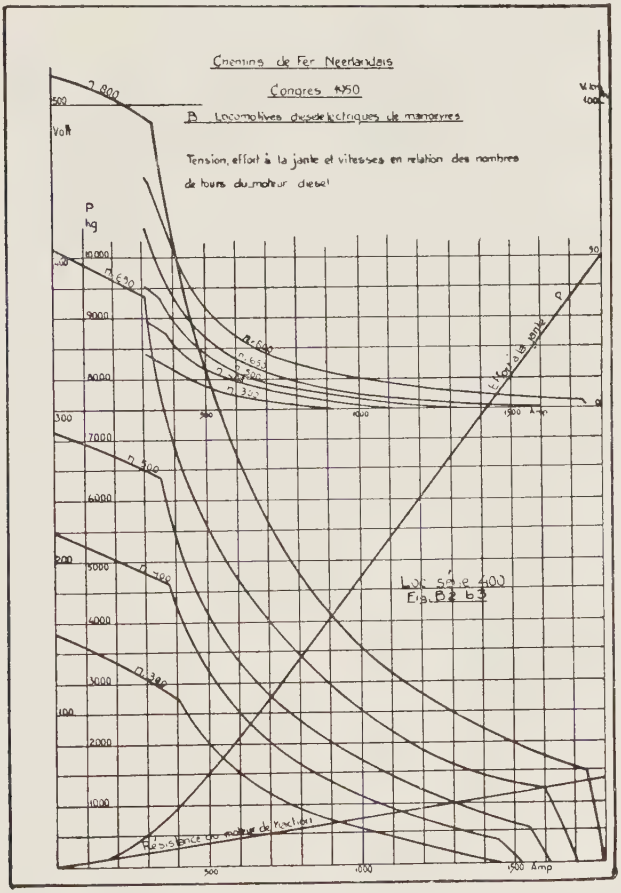

Chemins de Fer Neerlandais
Congres 1950
B Locomotives diesel-électriques de manœuvres
Tension, effort à la jante et vitesses en relation des nombres de tours du moteur diesel
Volt
P kg
Amp
Puissance du moteur diesel

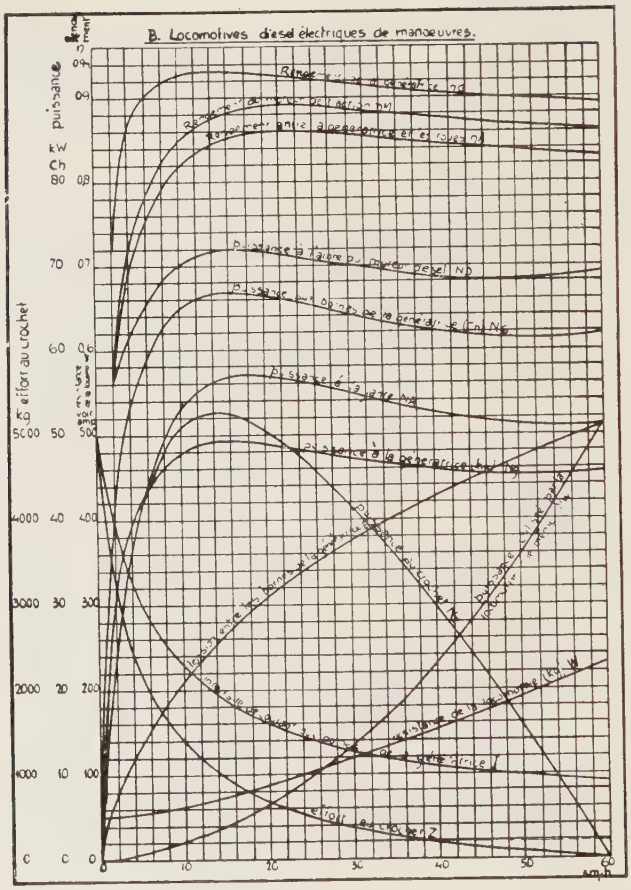
Fig. 14.

Explanation of French terms :

Chemins de fer Néerlandais = Netherlands Railways. — Congrès 1950 = 1950 Congress. — B. Locomotives Diesel-électrique de manœuvres = B. Diesel-electric shunting engines. — Tension, effort à la jante et vitesses en relation des nombres de tours du moteur Diesel. = Voltage, effort at tread and velocities according to r.p.m. of Diesel motor.

class of locotractors of 72 HP and have electric transmission, which is not often used on units of low power. The designation is Bo; the weight 21 t and the maximum speed 65 km/h. (40 miles). The Diesel engine is 4 stroke, 4 cylinders, 150 mm × 185 mm (5.9 × 7.3 in.); the electrical traction equipment is composed of one main generator and two series excitation traction motors, coupled in parallel. The starting of the heat engine is assured by a starting up motor; a lighting generator and an auxiliary generator complete the electrical equipment of these locotractors. The traction characteristics are shown in the diagrams given in figure 18.

Netherlands Railways.



Results of tests.
Diesel-electric locomotives types 201-209.

Fig. 15

QUESTION 3. — *Which are the results (if possible in figures and in comparison with steam traction) you actually obtained, and particularly on the following points :*

a) *average percentage of availability and utilisation in shunting (switching) service for a single locomotive of a certain type. Time for shopping and periodic inspections, daily inspections and repairs, ready for service (available) and service (working) to be considered separately.*

The *S. N. C. F.* gives the coefficient of availability for the Diesel locomotives as 95 % and that for steam locomotives, excluding the time required for refuelling and attending to the fire, 80 %; the average utilisation coefficient is 92 % for the Diesel locomotives; no figures are available for steam.

The *Danish Railways* give the coefficient of utilisation as 74 % for Diesel traction and 58 % for steam.

The *Italian State Railways* have obtained a coefficient of 97 % of availability and utilisation for the locotractors and of 75 % and 60 % respectively for the Diesel-electric locomotives.

The *Netherlands Railways* give the average availability of the Diesel locomotives as 37 %, and the *S. N. C. F.* the average utilisation as 53 %; these low values, it should be pointed out, are due to the fact that the locomotives which were bought from the English military authorities were already considerably worn;

b) *average number of vehicles shunted per day.*

The only replies received to this question were from the *Italian State Railways* who gave the average number of vehicles shunted per day by the locotractors as 14 to 15, and by the 650 HP locomotives, as 120.

The *Danish Railways* who report 19 vehicles per day shunted by the locotractors and 174 by the steam locomotives, and the *S. N. C. B.* who gave a figure of 500 vehicles per day. This figures seems unduly high and probably relates to all the locomotives in service. In this case, the number of vehicles shunted per day per locomotive would more or less agree with the values already given;

c) *average coefficient expressed as a percentage of utilisation of the tractive effort.*

The information supplied on this point was insufficient and too indefinite for any useful conclusions to be drawn therefrom. For example the *S. N. C. F.* estimate the coefficient of utilisation of the tractive effort as 30 % for the Diesel locomotives; the *Italian State Railways* give it as 70 % for the locotractors and 60 % for the locomotives, and the *Danish Railways* as 80 to 100 % for Diesel traction and 50 to 100 % for steam traction;

d) *possible drawbacks in service.*

It should be stated that in principle there has not been any report of any serious drawback to using Diesel locomotives. In the case of locotractors, the *Danish Railways* had some trouble with the coupling and gear boxes, due essentially to the frequent changes of speed which were rather hard to effect. The *Italian State Railways* have found the adhesive weight too low and experienced some difficulty with starting the Diesel engines during cold weather. The *S. N. C. F.* recommends that the buying of spare parts should be well organised in order to save trouble, and also that the number of different types in service should thereby be reduced. In the case of steam locomotives, on the contrary, trouble is experienced because of interruptions to the shunting due to refuelling and attending to the fire. In addition, from the heat point of view the steam locomotive is not considered to be well adapted to such intermittent work as shunting;

e) *first costs, based on actual prices, total and per HP, and resulting annual charges.*

As it was not possible to sum up the figures given in this connection, we give them below as received.

S. N. C. F.

Experience shows that the amortisation periods for Diesel locomotives and locotractors vary according to the type of machine. For example, they are taken as 15 years in the case of small machines with fast running engines, and as 35 years for the heavy locomotives with slow running engines.

The cost price, at present prices, and the fixed annual charges in the case of the 750 HP Diesel-electric locomotives are as follows :

Purchase price and delivery.	44 000 000 fr.
Fixed annual charges for amortisation over 35 years at the rate of 5 % . . .	2 680 000 fr.

The *Danish Railways* give the ratio between the cost price, sinking fund and interest charges as 2.5 ÷ 3 to 1 for Diesel shunting tractors and steam shunting engines, if of Danish manufacture.

Italian State Railways.

For the 105 HP locotractors :

Cost price . . . . . Lire	9 000 000
Fixed annual charges for amortisation over 15 years at rate of 5.5 %	895 000
For the 650 HP Diesel electric locomotives : estimated present value .	78 400 000
Fixed annual charges; amortisation over 20 years at 5.5 %. . .	5 860 000
For 6 wheeled steam locomotives, 45 t : estimated present value . . .	33 900 000
Fixed annual charges : amortisation over 30 years at 5.5 % . . .	2 230 000

Belgian National Railways Co.

For the 350 HP Diesel locomotives :

Cost price . . . . . B. fr.	4 000 000
Annual amortisation in 25 years.	144 000
Financial charges at interest of 4.25 %	170 000
For equivalent steam locomotives :	
Cost price	1 900 000
Amortisation in 40 years . . .	42 000
Financial charges at 4.25 % . .	80 000

Algerian Railways :

For the 340 HP Diesel-electric locomotives :

Cost price . . . . . Fr.fr.	14 000 000
Fixed annual charges.	933 000
For the 204 HP locotractors :	
Cost price . . . . . Fr.fr.	12 500 000
Fixed annual charges	833 000

f) *Operating costs per locomotive-hour, composed chiefly out of repairs, fuel lubrication, other supplies, maintenance, crew-wages and social charges, specified if possible for heavy-duty and working in average and small stations.*

S. N. C. F.

For the 750 HP Diesel-electric locomotives for 1948 :

Maintenance . . . . . Fr.fr.	292.52
Drivers.	260.34
Fuel	556.40
Lubricants	24.54
Other shed costs	155.04
Total costs Fr.fr.	1 288.84

Danish Railways.

Costs	60 HP locotractor	100 HP locotractor	200 HP steam locomotives
Fuel	29 öre	38 öre	450 öre
Lubricants	12 »	15 »	15 »
Maintenance	320 »	320 »	150 ÷ 200 »
Staff	350 »	350 »	350 »
	711 öre	723 öre	865 ÷ 915 öre

Italian State Railways.

For the locotractors :

Fuel . . . . . Lire	455
Lubricants	46
Driving staff	210
Maintenance	100
Total costs . . .	811

For the 650 HP Diesel-electric locomotives :

Fuel . . . . . Lire	850
Lubricants	350
Maintenance	200
Driving staff	535
Total costs . . .	1 935

For the Gr. 835 steam locomotives, 6 wheels, 45 t :

Fuel . . . . . Lire	1 200
Lubricants	27
Driving staff	535
Maintenance	200
Total costs . . .	1 962

Belgian National Railways.

The operating costs in francs per kilometre run (one hour's shunting being taken as 4 km run) were given. Below is given a comparison between the operating costs for 1948 in the case of an Armstrong-Whitworth Diesel locomotive and type 58 steam locomotives (38 t in running order) and type 53 (67 t in running order). The power of the Diesel locomotive lies between these two types of steam locomotive :

Costs	Diesel locomotive	Steam type 38	Steam type 54
	B. Frs.	B. Frs.	B. Frs.
Driving staff	9.20	15.10	15.37
Fuel	6.30	15.93	19.14
Lubricants	1.60	0.14	0.17
General costs	4.06	5.17	5.13
Preparation	0.42	0.88	0.94
Maintenance	3.33	3.23	3.60
Total	24.91	40.45	44.35

Algerian Railways.

	Costs	
	204 HP locotractor	340 HP locomotive
	Fr. fr.	Fr. fr.
Driving staff	178.4	178.5
Maintenance	178.5	357
Fuel	248.4	510
Lubricants	18.96	50.7
	624.26	1 096.2

g) *total repair-costs per unit of fuel consumed, and all further information that might be of use for this purpose.*

French National Railways.

The following information applies to the 750 HP Diesel-electric locomotives whose fuel consumption when shunting is 19.8 l/h. (4.4 galls.) :

General repairs . . . . . Fr. fr.	111.78
Intermediate repairs	30.66
General overhaul	27.72
Current maintenance and repairing breakdowns.	108.78
Total repair costs and maintenance costs per litre of fuel used.	278.04

Danish Railways.

The total repair and maintenance costs per unit of fuel used for the 60 and 100 HP tractors and the steam locomotives of approximately 200 HP are respectively 214 öre/l of fuel oil; 160 öre/l; 3 to 4 öre/kg of coal.

Italian State Railways.

For the locotractors, the total repair costs are 38.6 Lire per l of fuel; for the 835 HP locomotives 33 Lire per kg of coal, and for the 650 HP Diesel-electric locomotives 24.5 Lire per l of fuel, divided up as follows :

General repairs	7
Intermediate repairs	7.5
Current maintenance and repairing breakdowns.	10
Total . . .	24.5

Belgian National Railways.

The total cost of repairs per litre of fuel consumed for the 350 HP Diesel locomotive is 2.7 fr.

Algerian Railways.

For the 205 HP locotractors the figure is 19.7 fr./l and for the 340 HP locomotives 20.4 fr./l.

QUESTION 4. — *Which power do you consider the most convenient for your needs in freight-yards, big stations and small stations?*

In this connection all the Administrations agree that it is necessary to have a series of types of different powers, so that a high coefficient of use of the tractive effort can be obtained in most cases. The S. N. C. F. in particular as we have already stated expects to have available very shortly three classes of locotractors and 3 classes of locomotives, covering the whole range of powers from 30 to 150 HP and 360 to 750 HP.

In general, it is considered sufficient to have three classes of shunting engines, the average powers of which will be 50 to 100 HP; 150 to 250 HP and 400 to 700 HP.

QUESTION 5. — *Is the control of your shunting (switching) locomotives performed by a single man? If so, which are the special arrangements?*

The locotractors are driven by one man; as regards the Diesel locomotives used for shunting, the Italian State Railways and sometimes the Portuguese Railways, use two men, whilst the other Administrations never use more than one man.

In any case there is always a second man on the locomotive when it has to make a long run over the main lines. The locomotives of the Belgian National Railways, the Netherlands Railways, and the Swedish State Railways are fitted with a dead man's handle.

Considerations.

Shunting may be divided up into different categories according to the operations to be carried out, i.e. :

— movement of vehicles and engines in the sheds, shops and small stations;

— shunting in stations of average importance;

— heavy shunting operations and use in large marshalling yards.

In order to obtain as high a coefficient of utilisation of the tractive effort in the different cases as possible, it is recognised as being necessary to have a series of different types, which can be grouped, according to the most common classification, into three classes with powers of 50 to 100 HP, 150 to 200 HP and 400 to 700 HP.

The latter class should if necessary be reserved for Diesel locomotives with electric or hydraulic drive, whereas the other two

are suitable for locomotives with mechanical drive, which consequently cost a great deal less.

The result is that locotractors are already used on a wide scale; moreover even Diesel locomotives properly so-called are used to a great extent for shunting, and are nearly all equipped with electric drive. It must be pointed out however that many of these locomotives were taken over from the American army.

The locotractors used for shunting are always driven by one man only, which is also the case with the Diesel locomotives, except in a few countries, but not on account of technical reasons. The device known as the « dead man's handle » is only fitted to these locomotives by a few Administrations.

The coefficients of availability and utilisation of the Diesel shunting locomotives are in general fairly high and appreciably better than those for steam locomotives, whilst the operating costs are lower. In the case of locotractors, their particular advantage must be stressed when used instead of shunting locomotives for unimportant or intermittent shunting, or on secondary lines to haul the pick-up goods trains of limited size, with the additional task of shunting a few wagons in the small stations en route.

The considerable and increasing favour that Diesel traction is finding for shunting amongst many Administrations is therefore well justified, especially as it can often be used with advantage on the electrified lines.

C. — Railcars.

QUESTION 1. — *For what kinds of services do you use railcars?*

In most cases railcars are used for passenger traffic, mostly as stopping or through trains, on secondary lines and branch lines of the main lines with little traffic, for short runs.

The shortage of coaches after the last war resulted, especially in Europe, in a more extensive use of railcars than in the past, even as fast or express trains on main lines and over long distances.

The success of this technique, both as regards the engines and the construction in general, justifies the expectation that certain types of railcars or combinations of railcars and trailers will continued to be used for fast services over average and long distances, even on the main lines.

It is also likely that special services to meet tourist traffic will be developped.

The use of railcars for other than passenger services is very exceptional.

QUESTION 2. — *How many railcars have you, and what is the average age of the different types?*

The replies received to this question are summed up in the Table on pp. 1964/60 and 1965/61.

QUESTIONS 3 and 4. — *What type of railcar has proved best for each kind of service? For each type, give the weight empty, the maximum speed on the level, the seating capacity, the number of motors and their position, the total power per ton when the vehicle is fully loaded; the type of gear change.*

Please give detailed information about your different types of railcars, with details concerning their value and the application of recent technical improvements.

The replies received show that questions 3 and 4 are very closely linked and consequently we thought it best to take these two questions together in order to make our report more homogenous.

The examination was limited to replies concerning Administrations and types of railcars which on account of their lengthy experience and the importance of the services run are of the greatest value from

	Austrian Federal Railways Total : 28				*Belgian National Railways* Total : 108			*Czechoslovakia*	*Danish* T
Type of railcar	VT 41	VT 42	VT 43	VT 44	551	552	553	A, B, C, D	ML
No. of each type	9	9	1	9	52	6	50	Not stated	15
Average age in years	16	14	13	8	10	10	7		19

Italian secondary Railways Total : 10	*Luxemburg* Total : 10	*Norwegian State Railways* Total : 64				*Netherlands Railways* Total : 27			*Portuguese Railways Co.*	*Spanish Railways* Total : 49		*Swedish* T
		Type 6	Type 7	Type 8	Older types	OMbc	Triple rakes	Five-unit rakes	Railcars being built	4-wheeled	Bogie	Yo
10	10	—	—	—	—	3	18	6		6	43	37
14	—	10	9	4	—	12	15	9		—	—	11

	Swedish T			
	Yol	Yols	Yo2	
	90	33	9	
	6	1	11	

'ways			*French National Railways* Total : appr. 700							*Italian State Railways* Total : appr. 625						
	MB+FJ+AB+MB	MS+AA+MS	Light	Light	300 HP	600 HP	TAR Train-set	—	Other types	ALn 40	ALn 56	ALn 556	ALn 56 ca.	ALn 772	ATR	Other types
	5	3	25	25	400	100	30	100	20	10	145	207	9	192	5	57
5	12	14	15	1	15	10	15	15	—	15	14	12	13	10	12	16

'ways				*Belgian Light Railways* Total : 200	*Algerian Railways* Total : 5		*Lower Congo-Katanga Ry* Total : 2	*Damas-Hama Railway* Total : 4	*Gafsa Railway* Total : 4	*Franco-Ethiopian Railway* Total : 3	*Indochinese Railways* Total : 8	*Madagascar* Total : 8	*Mozambique* Total : 4	
	Y	Yg	Yt	Type for narrow gauge line	—	Renault zzg	De Dietrich zzn	—	De Dietrich	Brissonneau et Lots	Fiat	A T R	Brissonneaux et Lots	Michelin Panhard	Michelin Hispano
	67	2	1	73	—	3	2	2	4	4	3	8	2	2	2
	13	11	15	—	—	13	1	1	15	10	14	Not put into service	11	15	12

the points of view of analysing their construction and deducing the line of development.

The *Austrian Federal Railways* reported the following data concerning their stock of railcars :

Type	Weight empty tonnes	Max. speed	No. of seats	No. of motors and cylinders	Power of engines	Power per ton full load	Type of drive
VT 41	33	80	64	1/8	160	4.05	Electric. Diesel-motor and generator on one bogie and traction motors on the other.
VT 42	51	110	78	2/8	2 × 210	7.04	
VT 43	27.5	85	41	1/8	210	6.03	
VT 44	46.5	115	64	1/12	425	8.15	Engine and hydraulic drive set on one bogie.
VT 45	53	115	113	1/12	425	6.65	
VT 145	53	115	113	1/12	500	7.8	»

The VT 45 and VT 145 types are just being put into service.

Special technical arrangements have been incorporated in these latter railcars (see fig. 19), in which the passenger compartments have been arranged as double deckers, each 2 m (6.6 ft.) high, thus giving a total seating capacity of 113 in a 27 m (88.6 ft.) long vehicle.

The leading vestibule, at a normal height of 1.3 m (4.3 ft.) above rail level and in which a small bar has been arranged gives access to the lower compartment by means of four steps down, and to the upper compartment by 5 steps up. The bogies are of steel fabricated by welding the axles are of nickel-chrome steel. The Diesel engine and hydraulic drive are carried on one bogie, the two axles of which are coupled to the motor shaft by a cardan shaft. The other bogie is a *carrying* bogie. The body is built of steel sections and sheets electrically welded together.

The *Belgian National Railway Company* only uses railcars for stopping passenger trains on secondary lines with light traffic. The three types of railcars of which the Belgian stock consists are consequently of light construction : the greatest possible use is made of the space available for passengers, the speed and power installed being relatively low.

Only the 553 type, which with a special axle gear box can reach a maximum speed of 80 km/h. (50 miles) on the level is used for special services in connection with the tourist traffic.

The characteristics of the three types in question are as follows :

Type	Weight empty in running order tonnes	No. of seats	Maximum speed on the level km/h	Specific power under full load HP/tonnes
551	14.5	50	58	6.2
552	21.5	80	56	4.2
553	22.5	80	66	5.3

These three types of railcars are equipped with a single Diesel engine carried by the main frame of the vehicle with silent-blocs, towards the centre of the frame. The drive includes a disc clutch, a gear box (4 speeds) of the synchro-mesh type, a reserve gear with synchro-mesh wheels a differential and cardan shafts to drive the axles by worm and bronze wheel keyed on the axle.

In the 4 wheeled railcars, there are always two engines. The bogie railcars have a driving axle per bogie.

The *Czechoslovakian National Railways* have four different types of railcars in service, each of which has characteristics closely adapted to suit the kind of service for which it is used, i.e. :

Type A : for stopping services on local lines;

Type B : for stopping trains on the main lines over short distances;

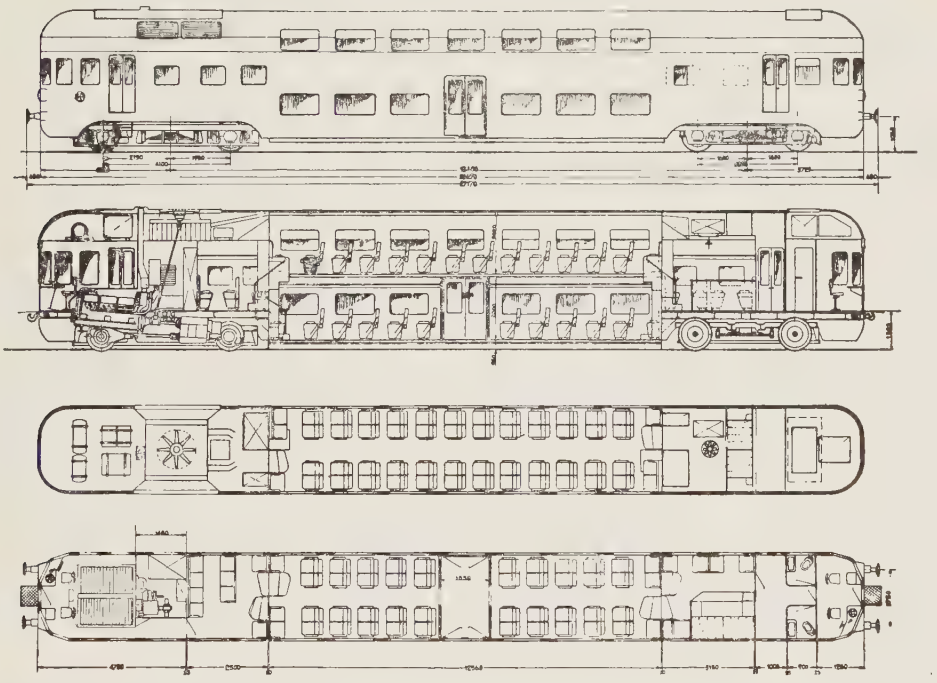


Fig. 16. — *Austrian Federal Railways.* — VT 145 railcar.

Type C : for fast local services where the trains are infrequent, to complete and improve the other services worked by the usual method of traction;

Type D : for high speed services over long distances.

The characteristics of these railcars are as follows :

Type	No. of axles	Weigh tonnes		Maxim. speed on the level km/h	Maxim. No. of seats	No. and output of motors HP	Position	Power per ton	Kind of drive
		empty	loaded						
A	2	15.5	20.7	60	48	1 × 155	on the frame of the vehicle	7.5	mechanical
B	4	42	47.5	90	56	1 × 410	on the bogies	8.5	electrical
C	4	50.5	58	110	60	2 × 300	»	10.4	»
D	6	91	97	130	76	2 × 410	»	8.5	»

The *Danish State Railways* railcars all have electric drive. The more recent types used for the fast important services and all the articulated rakes are equipped with ASEA type automatic speed control.

On the passenger railcars used on secondary lines, there is only one Diesel engine, both the specific power provided and the maximum speed are relatively low; in the more recent types used for high speed services, there are at least two Diesel engines, of greater power, and a maximum speed on the level of 120 km/h. (75 m.p.h.). The detailed characteristics for the more important types are summed up in the following table :

Type	Weight empty	Max. speed on the level km/h	No. of seats	Diesel motors	Position	Electric motors	Position	Total power per t/ full load HP	Speed gear
MQ	55.6	100	70	1	on one bogie	2	on the other bogie	4.7	Diesel engines regulated manually as is the resistance of the generators.
MO	59.3	120	52	2	»	2	»	8.1	ASEA automatic control.
MK/FK	118	120	116	2	» of the MK railcar	6	2 on each of the other bogies	7.9	»
MB+FJ+AB+MB	176.6	120	222	4	2 on each end bogie	4	»	5.3	»
MS+AA+MS	137.8	120	168	4	»	4	»	7.4	»

The technical characteristics of the most recent types are : the adoption of the ASEA automatic control; standardisation of the Diesel engines; direct injection.

The MK/FK rakes for fast services are fitted with a steam boiler with automatic oil burners to heat the twin units of which the train is composed, as well as the cooling water for the Diesel engines if necessary.

The *French National Railways,* amongst the different types of railcars built since 1933, only replied to the questions asked in the case of certain types which have proved particularly well adapted to the requirements of the services for which they are used.

The characteristics of these types are summed up in the following table :

Type	Weight empty tonnes	Max. speed on the level km/h	No. of seats	No. of motors	Poistion	Total power per t	Type of gear change	
Renault ABJ 300 H.P.	30	120	64	1	—	7.6	4 speed mechanical	
De Dietrich 2 × 160 H.P.	34	120	75	2	on the frame at the ends	7.4	Gears always in mesh 4 synchronised speeds	
Renault AD × 2 2 × 300 H.P.	43	126	88	2	»	11.8	»	
Decauville 2 × 320 H.P.	41	110	89	2 with electric generator	»	13	—	4 traction motors on the axles
T A R	130	150	138	»	on the outer bogies	5.5	—	4 traction motors 2 for each inner bogie

The basis of operating a service economically by railcars is stated by this Company to be the possibility of adapting the power available to the often varying traffic requirements. In this connection their long experience has led them to carry out their most recent constructions according to this principle, while the following principles will be still more rigorously taken into account in the new designs now being built or still under investigation :

a) high specific power and adhesive weight in the motor units so as to enable at least one trailer to be used;

b) possibility of coupling the railcars together as well as railcars and trailers;

c) construction of especially light trailers.

In addition the following technical improvements will be incorporated :

d) use of high speed Diesel engines;

e) mechanical injection;

f) installing the engines in the body;

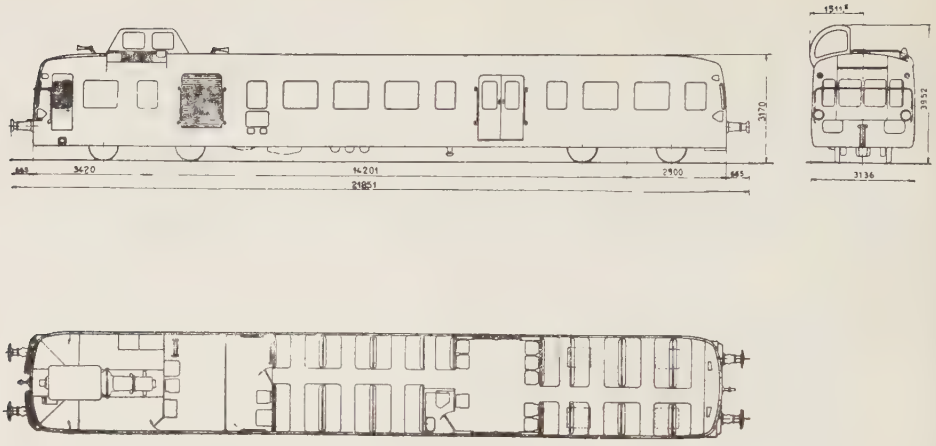


Fig. 17. — *French National Railways.* — 300 HP railcar.

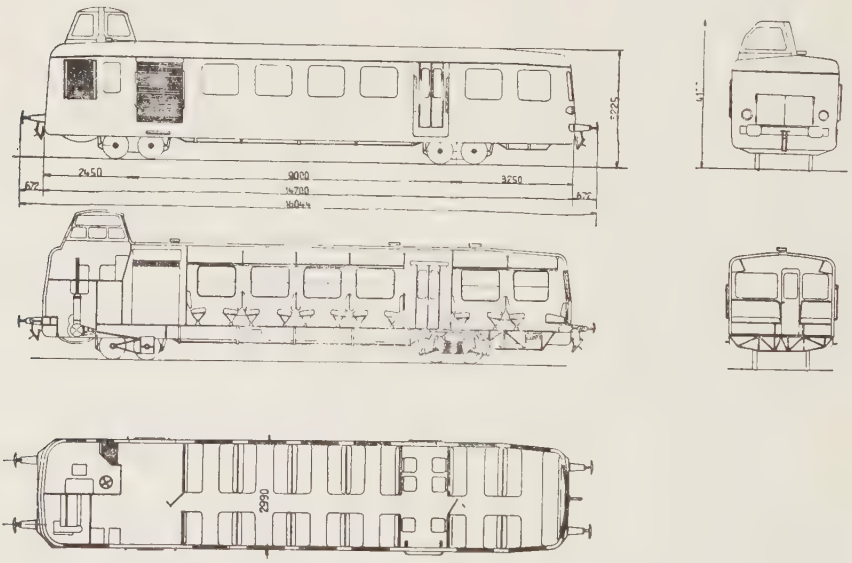


Fig. 18. — *French National Railways.* — 150 HP railcar.

g) mechanical transmission;

h) tubular components and framework

i) bogie suspension using coiled springs and hydraulic shock absorbers;

j) brakes with large area shoes applied on the tyres;

k) standardisation of the engines, the different components of the body and the running gear to the maximum possible extent;

l) reduction of the number of types to 5 in principle, with the following nominal powers :

1) 600-650 HP to haul a trailer and capable of being coupled up in pairs to work fast services over long distances;

2) 2 × 300 HP able to haul 1, 2 or 3 trailers according to the characteristics of the line in question, for through — or stopping services on lines with heavy gradients;

3) 300 HP able to haul a trailer, except up heavy gradients where two railcars, or two railcars and one trailer, will be coupled together for stopping trains, especially on cross country lines (see fig. 17);

4) 150 HP for secondary lines, with moderate gradients; these railcars must also be able to haul a trailer (see fig. 18);

5) 100 HP also for secondary lines with little traffic, which can haul a light trailer (see fig. 19).

The *Italian State Railways* who suffered greatly during the war and had almost 75 % of their pre-war railcars put out of action, have proceeded to repair and rebuild the following types. These are the types most suitable for the actual traffic requirements :

Type	Weight empty tonnes	Max. speed km/h	No. of seats	No. of motors and position	Total power per t	Type of gear charge
ALn 56 Fiat	20	110	56	2 on the bogies	6.0	Fiat : 4 speed gear box
ALn 56 Breda	28	130	56	2 »	8.5	Wilson 5 speed epicyclic
ALn 556 Fiat	23	110	56	2 »	6.00 9.00	Fiat : 4 speed gear box
ALn 556 Breda	28.7	130	56	2 »	8.5	Wilson 5 speed epicyclic
ALn 772	37	130	72	2 on the underframe at the ends	7.5	Lysholm Hydraulic
ALn 56 c. a.	24	70	56	2 on the bogies	9	4 speed gear box
A T R	110	115	115	2 »	7	Fiat : 4 speed gear box
RALn 60	30	70	60	2 under the frame	10.5	Fiat : gear box with 5 synchronised speeds
	26	70	60	1 under the frame	6.2	
ALn 880 Breda	40	130	80	1 »	10	Wilson 5 speed epicyclic
ALn 990 OM	40	130	90	1 »	9.8	Lysholm Hydraulic
ALn 990 Fiat	40	130	90	1 »	9.8	Fiat : gear box with 5 synchronised speeds

The first two types above are very well adapted for stopping trains over short distances, the ALn 556 railcar (see fig. 26 and 27) is adapted for the same services and can be coupled together as a twin unit with single control.

The 772 group (see fig. 28) is adapted for fast services, over long distances if necessary, and can be coupled together as twin units with single control.

In the 56 C. A. group of railcars, all the axles are driving axles; these railcars are in service on the Paola-Cosenza line where they climb gradients of 75 $^{0}/_{00}$ very satisfactorily.

The ATR articulated rake (see fig. 29) is composed of two motor units with a trailer in the middle, and is used for 1st and 2nd class express services on the main lines over long distances.

The RALn 60, ALn 880 and ALn 990 railcars are now being put into service (see questions 15 and 17).

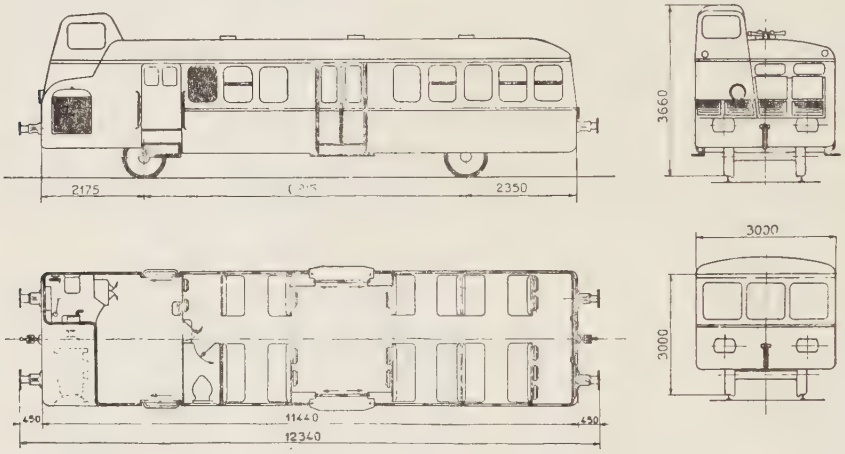


Fig. 19. — *French National Railways.* — 100 HP railcar.

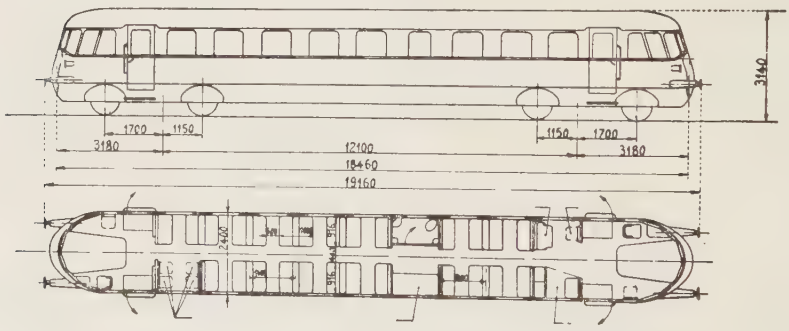


Fig. 20. — *Italian State Railways.* — Fiat railcar, type 556.

The *Veneta Company* operating the secondary Italian Railway services has 10 railcars very suitable for stopping services on lines on the level and hauling a trailer.

The characteristics of these railcars are as follows :

Weight empty in t	Max. speed on the level km/h	No. of seats	No. of motors	Position of motor	Power per t	Type of gear change
30	85	80	1	On one bogie	6	Mechanical 4 speed constant mesh gears

The *Luxemburg Railways* will have in service 10 De Dietrich railcars with two 160 HP Diesel motors, each with the following characteristics : weight empty 32.5 t; maximum speed 120 km/h. (75 miles); no. of seats 75; two Diesel motors fitted on the bogies; power per tonne under full load 7.375 HP with 4 speed synchronised gears.

The *Norwegian State Railways* replied to the question concerning the 3 most recent types of railcars, 6, 7 and 8. The following table sums up their reply :

Type	Weight empty tonnes	Max. speed km/h	No. of seats	No. of motors	Position	Power per t full load	Drive
6	28	100	79	2 × 185 HP	under the body in the middle of the vehicle	10	Lysholm Smith hydraulic
7	15	80	57	1 × 130 HP	at the front end of the body	7	»
8	112	120	152	2 × 650 HP	on the motor bogies at the ends	10.5	Voith

These railcars are characterised by the fullest possible use being made of the available space, except in the case of the type used for important services, and a high specific power.

The *Netherlands Railways* stress that owing to the fact that their lines are always on the level, the characteristics of the different types of railcars are determined by traffic requirements, i.e. the number of seats and maximum speed required. The three most numerous types (see fig. 32, 33, 34) have the characteristics given on the following page.

On the 3 and 5 unit articulated rakes the body frame and bogies are built up of sections and tubes welded throughout; the fittings and accessories are of light metals. There are two driving compartments, one at each end. The cooling water for the Diesel engines is used for heating, and in very cold weather the heat is reinforced by a boiler burning heavy oil. The burner is controlled by a thermostat in the cooling water circuit. The temperature inside the coaches is also regulated by thermostat.

Type	Weight empty tonnes	Max. speed on the level km/h	No. of seats	No. of Diesel motors	Position	Total power per t under full load	Type of gear change
OMbc	53	100	71	2 × 150 HP	On the bogies	4.95	Mylins 4 speed
Triple rake	101	125	160	2 × 410 HP	On the body of the centre unit each coupled to an electric generator	6.98	— 4 traction motors 2 on each center bogie
Five-unit rake	237	140	272	3 × 140 HP	In an engine compartment	7.05	— 6 traction motors 3 for each 6 wheeled bogie of the motor unit

Two rakes can be coupled up as a twin unit, with single drive, the driver receiving a direct indication of the number of r.p.m. of the motors and the temperature of the cooling water for the other rake as well. The two rakes are coupled together automatically, both as regards the draw gear, the brake pipe and the control circuits when the two rakes come into contact.

The *Spanish National Railways* did not give any figures concerning the operating results with the different railcars.

Their characteristics are summed up in the following table :

Type	No. of axles	Weight empty tonnes	Max. speed on the level km/h	No. of seats	No. and position of motors	Power per tonne under full load.	Type of gear change
Renault	2	10	90	42	1 on the frame	8.14	Mechanical
Ganz	2	17	90	46	1 »	5.71	»
Frichs	4	41.5	90	72	1 on 1 bogie	5.00	— Electric transmission
Ganz	4	36.9	100	85	1 »	6.32	Mechanical
Fiat	4	30	100	92	2 on the bogies	7.63	»
Renault	4	31.5	107	70	1 on the frame	7.89	»
Ganz	4	44.8	100	94	1 on 1 bogie	7.44	Electric transmission
Maybach	4	42	110	80	1 »	8.54	»

The *Swedish State Railways* gave the following characteristics for their types of railcars most widely used :

Type	Weight empty tonnes	Max. speed on the level km/h	No. of seats	No. of standing	No. of motors	Power per ton under full load	Type of gear chang.
Y	7	80	24	40	1	7.9	4 speed mechanical
Yo	10.3	80	46	44	1	8.2	»
Yol	11	80	48	42	1	9.0	»
Yols	12.6	80	48	42	1	8.8	»
Yo2	25	110	66	14	2 for the frame	7.1	hydraulic
Yo3	26.6	110	65	33	»	9.4	»

The most notable features are : very low empty weight as the bodies are usually made of wood; greatest possible use made of the available space and power to haul very light trailers. The possibility of one man driving several railcars coupled together is under study, the engines and safety devices being coupled up electro-pneumatically (see fig. 35 and 36).

The *Belgian National Light Railways* have the following types of railcars in service on short runs with frequent stops :

Type	Weight empty tonnes	Max. speed on the level km/h	No. of seats	No. of standing	No. of motors	Position	Power per t under full load	Type of gear change
Brossel 130 HP Gardner 105 HP	10.5	60	24	40	1	engine and gearbox group suspended from the frame between the two axles.	8.7 7	Mechanical 4 speed, non-synchronised.
160 HP	19	60	30	48	1	» between the two bogies.	6.55	Mechanical 4 speed.
GM 160 HP Deutz 180 HP	18.5	64	52	48	1	»	6.4 7.2	Mylius 4 speed synchronised and preselective.

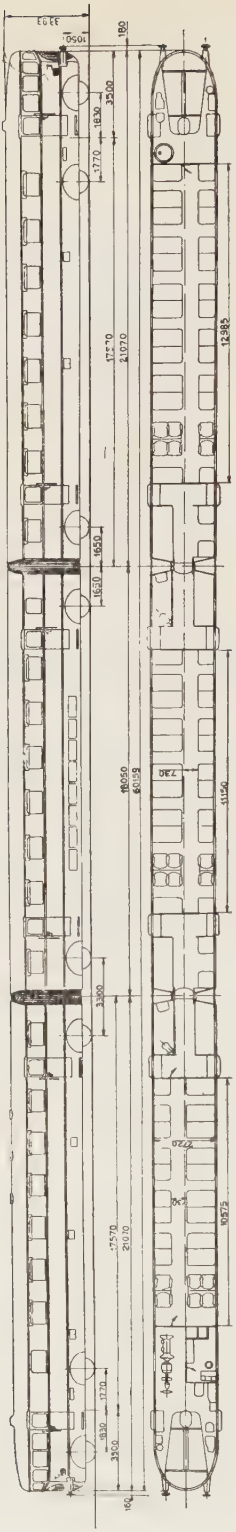


Fig. 21. — *Italian State Railways.* — Fiat Railcar set.

The most recent types have 2 stroke or 4 stroke engines, Mylius preselective, synchronised 4 speed gears; pneumatic clutch synchronised with the gear box; bevelled gear axle bridges; monobloc body forming frame.

QUESTION 5. — *What is their performance on up gradients? Average and maximum lengths of runs made by a railcar in normal working.*

The replies received are summed up below :

Austrian Railways. — The average daily mileage is approximately 320 km (199 miles), the maximum mileage 480 km (300 miles). The VT 42 and VT 44 types of railcars are most suitable for difficult runs; they can haul a 23 t trailer on an up gradient of 25 $^{0}/_{00}$.

The average monthly mileage lies between 7 000 km (4 350 miles) for the VI 41 type railcars and 9 000 km (5 600 miles) for the VT 44 type.

Belgian National Railways. — The maximum speed of the bogie railcars is 66 km/h. (41 miles) on up gradients of 5 $^{0}/_{00}$, 50 km/h. (31 miles) on up gradients of 10 $^{0}/_{00}$, 40 km/h. (25 miles) on up gradients of 15 $^{0}/_{00}$ and 26 km/h. (16 miles) on up gradients of 20 $^{0}/_{00}$.

The four wheeled railcars will climb the same gradients at maximum speeds of 58, 50, 38 and 25 km/h. (36, 31, 24 and 16 miles) respectively.

The average daily mileage is 240 km (149 miles); the maximum 460 km (286 miles); the capacity of the fuel tank limits the run to about 500 km (310 miles).

Czechoslovakian Railways. — The maximum speeds of the types A, B, C and D railcars, 60, 90, 110 and 130 km/h. (37, 56, 68 and 81 miles) respectively, can be observed on maximum gradients of 14, 10, 8 and 2 $^{0}/_{00}$ without trailers.

The average daily mileage is 180 to 250 km (110 to 155 miles) for type A, 300

to 400 km (186 to 249 miles) for types B and C, and 400 to 800 km (249 to 497 miles) for type D.

Danish State Railways. — In view of the hilly nature of this railway system, Denmark has no information to report.

The average and maximum mileages for railcars without returning to the sheds are 650 and 1 070 km (404 and 665 miles) respectively.

The average daily mileage of the railcars in service is about 400 km (249 miles).

The longest daily run made by an individual railcar is the 630 km (391 miles) journey from Bordeaux to Lyons.

Italian State Railways. — All the railcars are good at climbing gradients, and with the exception of those with hydraulic gears, can easily climb gradients of 35 $^{0}/_{00}$.

On gradients of 25 $^{0}/_{00}$, which are typical

Fig. 22. — *Swedish State Railways.* — 2 yols railcars and one UeFol trailer.

French National Railways. — No details concerning the way the French railcars climb gradients. The 2 × 160 HP De Dietrich type has the following characteristics : maximum speed on the level 120 km/h. (75 miles), on gradients of 5 $^{0}/_{00}$ 115 km/h. (71 miles), 10 to 15 $^{0}/_{00}$ 78 km/h. (48 miles), 20 to 25 $^{0}/_{00}$, 45 km/h. (28 miles). The Renault ABJ 4 type recently put into service can run at 107 km/h. (67 miles) on the level, 90 km/h. (56 miles) up gradients of 5 $^{0}/_{00}$, 88 km/h. (55 miles) up 10 $^{0}/_{00}$, 65 km/h. (40 miles) up 15 $^{0}/_{00}$ and 54 km/h. (34 miles) up 25 $^{0}/_{00}$.

of the Italian system, the speed of railcars under normal load is between 36 and 55 km/h. (22 and 34 miles) according to the type.

The ALn 56 railcars can climb gradients of 75 $^{0}/_{00}$ at about 20 km/h. (12 miles).

The average monthly mileage of the railcars in regular service is 7 500 km (4 660 miles).

The longest daily run is 650 km (404 miles).

Luxemburg Railways. — The performance expected of the railcars under order is remarkable being :

1st gear gradients	65 °/₀₀	25 km (16.5 miles)/h
2nd	36 °/₀₀	26 km (16 miles)/h
	32 °/₀₀	46 km (28.5 miles)/h
3rd	19 °/₀₀	47 km (29 miles)/h
	15 °/₀₀	78 km (48.4 miles)/h
4th	9 °/₀₀	79 km (49 miles)/h
	3 °/₀₀	120 km (75 miles)/h

Average daily mileage 260 km (162 miles).

Norwegian State Railways. — All the types 6, 7 and 8 can develop satisfactory speeds — about 40 to 45 km/h. (25 to 28 miles) up gradients of 25 °/₀₀.

Spanish Railways. — A speed of about 50 km/h. (31 miles) can be developped on up gradients of 20 °/₀₀.

Swedish State Railways. — The railcars do not have to slow down appreciably unless the gradients exceed 10 °/₀₀.

The average daily mileage varies up to a maximum of 750 km (466 miles).

Belgian Light Railways. — Average daily mileage: 250 km (155 miles) for 4 wheeled railcars, 500 km (310 miles) for bogie railcars.

Algerian Railways. — The speeds of the two types of railcars are:

90 km (56 miles)/h up gradients of 10 °/₀₀.
70 km (43 miles)/h up gradients of 15 °/₀₀.
45 km (28 miles)/h up gradients of 20 °/₀₀.

Damas-Hama Railways. — Speed up 12 °/₀₀ gradients: 65 km/h. (40 miles); 20 °/₀₀ gradients: 50 km/h. (31 miles).

Average daily mileage 390 km (242 miles).

Gafsa Railway. — The railcars in service on this line reach a maximum speed of 100 km (62 miles) on the level, 81 km/h. (50 miles) up gradients of 5 °/₀₀, 66 km/h. (41 miles) up gradients of 10 °/₀₀ and 55 km/h. (34 miles) up gradients of 15 °/₀₀.

Average daily mileage 222 km (138 miles).

Franco-Ethiopian Railway. — This Company's three railcars have a specific power of 9 HP per ton at full load, mechanical gear change and can reach a speed of 70 km/h. (43 miles) on the level, and 60 km/h. (37 miles) up gradients of 25 °/₀₀.

Indochinese Colonial Railways. — The railcars are designed to haul 15 t trailers. With a gear ratio at the axle of 28 : 32, the maximum speed on the level and gradients of up to 15 °/₀₀ is 72 km/h. (45 miles); the railcars can climb gradients of 25 °/₀₀ at 50 km/h. (31 miles). With a 15 t trailer the maximum speed is 72 km/h. (45 miles) on gradients up to 10 °/₀₀ and 32 km/h. (20 miles) on gradients of 25 °/₀₀. With two trailers (30 t) gradients of 15 °/₀₀ can be climbed at 50 km/h. (31 miles) and with three trailers (45 t) the same speed can be maintained on gradients of 10 °/₀₀.

QUESTION 6. — *Which are the results (if possible in figures and in comparison with steam traction) you actually obtained and especially on the following points:*

a) *average monthly mileage; average percentage of availability and utilisation for a unit of a certain type. Time for shopping and periodic inspections, daily inspections and repairs, ready for service (available) and service (working) to be considered separately;*

b) *nature and frequency, with regard to the number of trains, of the troubles that may lead to disturbances in train-service;*

c) *first costs, based on actual prices, and resulting annual charges;*

d) *operating costs per mile, composed chiefly out of repairs, fuel, lubrication, other supplies, maintenance, crew-wages and social-charges, exactly specified if possible for the different types of railcars.*

The replies received to this question cannot be compared for the following reasons: only a small number of the Administrations concerned were able to base their replies on actual experience; some of the ques-

tions, proved very complex and their interpretation proved uncertain, and finally the service situation and operating facilities resulting from the war have not yet returned to normal and the difficulties caused by the war have not yet been overcome.

For this reason we prefer to limit ourselves to reporting the information supplied by those Administrations able to answer these questions.

The table pages 1980/76 and 1981/77 sums up the information received in the case of points *a*) and *b*) above.

The above figures dealing with the average monthly mileage certainly refer to the total number of railcars of the type in question in service, in reserve and under repair in the case of Belgium, France, Italy, and the Damas-Hama Ry. We are not sure if this is the case with the other railways or whether the figures given merely refer to the railcars actually in service.

Comparison of the above figures with similar figures for steam traction has not been carried far enough to serve any useful purpose as far as we are concerned. This is also the case with regard to the nature of drawbacks.

The small number of drawbacks reported do not allow of comparison and the kind of drawbacks to be taken into consideration has not been stated. For example Belgium has been very severe and included delays up to 10 min. as well, which explains the high figure quoted. Italy has only included incidents leading to delays of more than 15 min. in the case of express trains and 30 min. for other trains, as well as every demand for a spare locomotive.

As regards purchase price at present values and the resulting fixed annual charges, the values given were :

Austrian Railways (in Schillings) :

	VT 41 1 200 000	VT 42 1 750 000	VT 145 2 000 000
Amortisation	48 000	85 000	100 000

Belgian National Railways (in Belgian francs) :

	Type 551 1 500 000	Type 552 2 000 000	Type 553 2 250 000
Amortisation	77 000	100 000	112 500
Financial charges	63 700	85 000	95 000

French National Railways (in French francs) :

Type	600 HP 41 000 000	300 HP 28 000 000	150 HP 17 000 000
Annual amortisation	4 814 000	3 248 000	1 972 000

Italian Railways (in Lire) :

Type	ALn 56 35 000 000 approx.	ALn 556 38 000 000 approx.	ALn 772 47 000 000 approx.
Annual amortisation	2 925 000	3 175 000	3 825 000
Annual financial charges	1 825 000	2 100 000	2 575 000

Italian Secondary Railways — Società Veneta — (in Lire) :

			40 000 000
Annual financial charges			2 100 000

Norwegian State Railways (in Crowns) :

	Type 6 280 000	Type 7 145 000	Type 8 1 360 000
Fixed annual charges		25 000 approx.	

	Austrian Railways			*Belgian Railways*	*Czechoslovakian Railways*			
	VT 41	VT 42	VT 44		A	B	C	D
Average monthly mileage in km	7 000	8 000	9 000	4 600	5 000	8 000	8 000	10 000
Average coefficient of availability %	45	66	78	78	—	—	—	—
Coefficient of utilisation in normal working %	—	—	—	63	85	82	81	81
Irregularities in service owing to breakdowns per 100 000 train/km .	Not given			4	Not given			

Spanish Railways. — This railway gives the present cost price of a standard railcar as 30 millions French francs.

Swedish Railways. — The cost price of the series Yo, Yol and Yols railcars is about 80 000 Swedish Crowns.

Belgian National Light Railways :

4 wheeled railcars : 1 100 000 B. Frs.
Bogie railcars : 1 750 000 B. Frs.

As regards point *d*) of the question, the replies giving the most detailed information are summed up below.

Belgian National Railways (in Belgian francs) :

	Driving staff	Fuel	Lubricant	Maintenance and repairs	Total
Type 551	2.07	0.66	0.14	4.17	7.04
Type 552	2.40	0.76	0.22	4.99	8.37
Type 553	2.40	0.81	0.22	5.45	8.88
Average	2.29	0.74	0.19	4.87	8.09

The average operating costs are about one third of those for a steam train equivalent to a type 552 or 553 railcar, consisting of a light tank engine and a metal coach with room for 94 passengers seated and 50 standing.

Italian ate Railways		*Norwegian Railways* type 7	*Netherlands Railw.* triple-rake	*Spanish Railways*	*Swedish Railways* Yo, Yo, Yo1s	*Belgian Light Railways*		*Danish Railways*	*Damas-Hama Railways*	*Gafsa Railways*
ALn 556	ALn 772					4 wheeled	bogie			
6 000	6 500	5 000	10 000	6 000	9 000	6 000	10 000	12 000	6 000	6 675
82	82	80	84	70	75	80	70	—	75	—
77	75	—	—	—	30	—	—	—	50	75
0.9		Not given	Not given	2.2	Not given	Not given		1.35	Not given	Not given

Czechoslovakian Railways (in Crowns) :

	Driving staff	Fuel	Lubricants	Maintenance and repairs	Total
Type A	2.50	3.30	0.25	1.74	7.79
Type B.	2.50	4.60	0.31	2.00	9.41
Type C.	2.50	6.40	0.63	2.30	11.83
Type D	5.00	7.40	0.80	4.00	17.20
Average	3.12	5.42	0.50	2.51	11.55

Danish State Railways (in Crowns) :

	Driving staff	Fuel	Lubricants	Maintenance	Total
500 HP railcars . . .	0.20	0.25	0.03	0.35	0.83
1000 HP railcars. . .	0.20	0.43	0.04	0.50	1.17
Average	0.20	0.34	0.035	0.425	1.00

Compared with the costs of operating a steam locomotive of equivalent power, the above figures show a saving of about 45 %.

French Railways (in francs) :

	Driving staff	Fuel	Lubricants	Maintenance	Total
300 HP type 1 engine.	12.66	15.40	1.33	40.85	70.24
300 HP type 2 engines.	9.53	14.10	1.65	56.73	82.01
600 HP type	13.27	23.60	2.33	51.78	90.98
Average.	11.82	17.70	1.77	49.78	81.07

Italian Railways (in Lire) :

	Staff	Fuel	Lubricants	Maintenance	Total
Type ALn 556 . . .	30.00	17.50	6.—	55.—	108.50
Type ALn 772 . . .	30.00	21.—	5.—	60.—	116.—
Average	30.00	19.25	5.50	57.50	112.25

Italian Secondary Railways — Società Veneta — (in Lire) :

	Staff	Fuel	Lubricants	Maintenance	Total
	35	42.5	13	12.5	103

Norwegian Railways (in Crowns) :

	Staff	Fuel	Lubricants	Maintenance	Total
Type 7	0.25	0.06	0.01	0.43	0.75

Netherlands Railways (in Florins) :

	Staff	Fuel	Lubricants	Maintenance	Total
Triple rake	0.076	0.052	0.018	0.153	0.299

Swedish Railways (in Crowns) :

	Staff	Fuel	Lubricants	Maintenance	Total
Yo, Yo1, Yo1s . . .	0.16	0.06	0.004	0.28	0.504

Damas-Hama Railway (in francs) :

	Staff	Fuel	Lubricants	Maintenance	Total
	10.05	3.10	3.40	7.00	23.55

The above figures, given as a percentage of the total railcar mileage run, if only the average values are taken, may be summed up as follows :

	Belgium	*Czechoslovakia*	*Denmark*	*France*	*Italy*	*Italian Secondary Railways*	*Norway*	*Holland*	*Sweden*	*Damas-Hama*
Driving staff.	28.5	27.0	20.0	14.5	27.0	34.0	33.5	25.5	32.0	42.3
Fuel	9.2	47.0	34.0	22.0	17.1	41.5	8.0	17.5	12.0	13.0
Lubricants.	2.3	4.2	3.5	2.2	4.9	12.5	1.5	6.0	0.8	14.5
Maintenance	60.0	21.8	42.5	61.3	51.0	12.0	57.0	51.0	55.2	30.0

A comparative analysis of the above figures shows that the cost of the driving staff is very similar in all cases if the different nature of the services run by the different Administrations is taken into account.

The costs of maintenance and repairs also agree, apart from the figures quoted by Czechoslovakian, the Italian Secondary Railways and the Damas-Hama Railway.

The figures given for fuel and lubricants are harder to understand, as it is not easy to see why they should vary so much, even taking into account possible differences in cost due to import dues, etc., and the differences between the types of railcars used and the services worked with them. The Spanish Railways reported a figure of 3.55 pesetas par railcar-kilometre in the case of bogie railcars and 1.77 pesetas in the case of 4-wheeled railcars. On the Belgian Light Railways the cost per railcar-kilometre run is 11 Belgian fr.; on the Gibuti-Addis-Ababa Railway the cost is 28 fr. per railcar-kilometre compared with 122 fr. for a steam locomotive.

QUESTION 7. — *As regards the different kinds of service, what increase in the average speed have you obtained by substituting railcars for steam trains?*

The substitution of railcars for steam trains generally results in making it pos-

	Austrian Railways	*Belgian Railways*	*Czechoslovakian Railways*	*Danish Railways*	*French Railways*	*Italian Railways*	*No Ra*
Train-km by railcars .	6 160	24 170	—	23 800	87 000	65 000	
Train-km by other methods of traction . .	141 100	109 000	—	32 800	340 000	245 000	6
% of mileage by railcar	4.4	18	29	42	20.5	21	

sible to run services at more frequent intervals on the various lines, and considerably increasing the average speed, by 20 to 35 % in the case of stopping trains according to the profile of the line, the number of stops and the nature of the corresponding steam services. The increase in the speed is generally less, being about 15 to 20 %, in the case of fast trains over long distances compared with the speed of steam trains formerly classified as « express » trains.

Certain special services which we will deal with can be classified in a different way.

On the *Algerian Railways* the increase in speed is 30 to 60 %.

On the *Belgian Railways* the speed of the railcars is the same as that of the so called « light » steam trains, which, headed by suitable locomotives, already had a satisfactory average speed. The increase in the speed compared with steam trains of standard composition is 15 %.

This low figure results from the low maximum speeds characterising the three types of railcars in service.

On the Beirut-Aleppo line, the *Damas-Hama Railway* found that railcars made it possible to increase the average speed by about 100 %. A considerable increase of the same order was obtained on the Gafsa-Sfax line.

On the *Italian State Railways* an increase of 50 % or more in the average speed was obtained in the case of stopping trains on lines with heavy gradients.

On the *Gibuti-Addis-Ababa Railway* the increase in the average speed was about 60 %.

QUESTION 8. — *What is the total number of train/kilometres run by railcars and by other methods of traction in the case of the passenger services.*

The replies received are summed up in the above table.

QUESTION 9. — *Do you couple up trailers to your railcars? If so, how many and what are their characteristics? Are passengers able to get from the railcar to the trailer? How much does the use of such trailers lower the average speed?*

The use of trailers with railcars is already very extensive and well organised on certain railways.

Other Administrations are going from the experimental stage to practical realisation, whilst on a small number of railways, generally those where not much traffic is carried by railcars and their use is limited to certain special service, no provision is being made for the use of trailers in the near future.

...r-s ...ays	*Spanish Railways*	*Swedish Railways*	*Belgian Light Railways*	*Algerian Railways*	*Damas-Hama Railway*	*Gafsa Railway*	*Franco-Ethiopian Railway*	*Mozambique Railways*
...00	5 795	—	37 800	960	790	870	330	95
...30	—	—	128 000	12 000	1 045	855	1 185	710
	—	25	23	7.4	43	51	22	12

The few railcars on which it is possible to pass from railcar to trailer are all of very recent construction.

The reduction in the average speed due to hauling trailers is not very great where the power of the motor unit and the weight of the trailer are properly proportioned to the permissible maximum speed on the line and its profile.

In particular, the *Austrian Federal Railways* couple up one or two 10 t trailers to their VT 41 railcars and 20 to 30 t trailers to their VT 42 and VT 44 railcars.

There are bellows giving access between railcar and trailer for the use of the train staff only.

On lines on the level, there is no reduction of speed with a trailer; the speed may be reduced by as much as 25 % on lines with heavy gradients.

The *Czechoslovakian Railways* add one, two or three trailers to the A, B and C types of railcars. It is possible to pass from railcar to trailer, and from trailer to trailer, by a gangway without bellows.

Trailers for the A type railcars have 4 wheels, weigh 11 tons and seat 48 passengers, whilst those for the B and C types have 8 wheels, weigh 30 t and seat 88.

The *Danish Railways* use 3 to 4 trailers on gradients up to 10 $^{0}/_{00}$. The more recent types have vestibule connections.

The reductions in the average speed resulting from the use of trailers are clearly shown in a practical example in the case of type Mo railcars on a 110 km (68 miles) long run with 18 stops. The time taken to make this run, in minutes, for the different cases under consideration are given in the following table :

Weight of the train at the railcar drawbar		0 ton	40 tons	80 tons	120 tons
Stops at every intermediate station	Maximum Speed 120 Km/h	93.5	105.5	117.0	127.5
	Maximum Speed 100 Km/h	96.0	107.5	118.0	128.5
	Maximum Speed 90 Km/h	101.0	110.0	119.0	129.5
Without stopping at intermediate stations	Maximum Speed 120 Km/h	67.0	76.5	83.0	92.5
	Maximum Speed 100 Km/h	74.0	80.0	84.5	93.5
	Maximum Speed 90 Km/h	80.0	82.5	87.5	97.0

On the *S. N. C. F.*, the use of trailers is current practice and very widespread. With a stock of some 700 railcars, there are a further 260 trailers, 85 of which are of recent construction, 40 rebuilt from old railcars, and 135 adapted from ordinary coaches; it is only possible to pass from one unit to another in the case of the TAR articulated rakes.

All recent railcars are designed in principle to haul trailers, even the low power units intended for secondary lines with little traffic.

The timetables are based on the operating requirements with the maximum load allowed for the motor unit.

The *Italian State Railways* so far have not used trailers on a large scale. The power of the railcars has been kept within the limits of good utilisation for services worked by one railcar or several railcars coupled together as required by the traffic. It should be mentioned that all the recent railcars can be coupled up in pairs, including the drive and signalling and safety devices.

The new types ALn 880 and ALn 990 which will be put into service this year are however designed to haul trailers. In the case of these railcars as in the case of the railcars and trailers it is possible to get from one unit to another, as well as to couple them and drive them from either the first or the second unit.

In the case of the new type RALn 60 railcars for the narrow gauge (0.95 m = 3 ft. 1.4 in.) lines in Sicily, now being delivered by the Fiat Company, a few units of which are already in service, trailers can also be used. They have been ordered from the same firm together with the railcars.

The *Norwegian Railways* have 16 trailers for their type 6 railcars. Some of these vehicles can be driven from the trailer; it is possible to pass from one unit to the other.

The *Netherlands Railways* have 19 trailer vans for the postal services in service, which can be coupled up to the electric or Diesel-electric railcars. In view of the purpose for which they are used, it is not possible to pass from them into the railcar, and there is no reduction in the speed if only one trailer is being hauled.

The *Swedish Railways* make it a practice to let all their different types of railcars haul trailers.

These trailers are of different types, the most important having the following characteristics :

Series	UF 2	UC Fol	UC Fo2s
Weight (t)	2.2	10.9	8.3
No. of seats	—	40	30
Area of van in m^2...	9.4	6.2	8.4
	4 wheels	bogie	bogie

It is not possible to pass from motor coach to the trailer. When hauling trailers, the speed is not reduced by more than 10 %.

The *Belgian Light Railways* let their 4 wheeled railcars haul trailers weighing about 4.5 t and their bogie railcars haul 7.5 t trailers. It is not possible to pass from one unit to the other; the speed is reduced by about 10 %.

QUESTION 10. — *Do you impose speed restrictions on railcars with one or more trailers ?*

All the replies agreed that no speed restrictions are imposed owing to the use of trailers.

QUESTION 11. — *Do you use coupled up railcars remote controlled from the leading unit ? If so, how many ?*

Only certain Administrations have made provision for coupling up and remote control from the leading unit on some types of railcars.

In *Czechoslovakia* this is possible in the case of the B, C and D types of railcars, but limited to two units of the same type. The method used was not explained.

The *Danish Railways* can do so with all the types of railcars fitted with ASEA automatic regulation.

It is also possible to make up trains with two Mo type railcars at the ends and 3 or 4 coaches in the middle, driven by the leading railcar, provided the coaches can be coupled up together and also to the end railcars.

On the *S. N. C. F.* a large number of railcars can be coupled up and remote controlled from the leading unit. To keep a better check on the engines, it has been found necessary to retain a driver on each unit. Consequently though the driver of the leading unit can work the brakes of all the units, the engines of the other units are driven by their own drivers. Acoustic signals make it possible for the leading driver to direct the others by suitable equipment.

This involves using more men, but makes it possible to simplify the equipment of the railcars very considerably.

On the *Italian State Railways,* it is possible to couple up and drive from the leading unit in the case of the most recent ALn 556 and ALn 772 types, as well as those now being built. Two railcars of the same type can be coupled together in this manner, but not more than two. The of r.p.m. of the motors on the trailing unit, the regularly of running, and the engine oil and cooling water, are shown on the leading unit.

In view of the high percentage of services worked by means of a double railcar (67 000 tr./km [41 632 miles] compared with 119 000 railcar/km [74 000 miles] per day), the saving of staff obtained in this way more than makes up for the cost of the equipment installed and its maintenance.

On the *Norwegian Railways* it is possible to couple up two units in the case of the type 6 railcars and type 8 articulated rakes.

On the *Netherlands Railways* it is possible to couple up two articulated rakes, and drive them from the leading unit. The engine r.p.m. as well as the temperature of the cooling water on the second unit are shown on the leading unit.

It is also possible to drive from the leading unit when 3 or 4 articulated rakes are coupled together, but in this case the temperature of the cooling water and the engine r.p.m. of the last or two last rakes cannot be checked by the driver.

Consequently in this case it is necessary to have an extra man to look after the engines of these rakes.

The *Swedish Railways* have made provision for the railcars now under construction to be coupled together.

QUESTION 12. — *Do you use articulated railcars? If so, what results have been obtained?*

The railways with articulated units in service are those of Algeria (Renault twin units), Czechoslovakia (type D), Denmark (various types), France, Italy (ATR) and the Netherlands. The characteristics of these articulated rakes were given when dealing with questions 3 and 4 of the questionnaire.

The operating results obtained with those railcars are generally stated to be satisfactory.

On the other hand, the French Railways report the solution of having articulated rakes consisting of two railcars with a trailer in between, the whole mounted on three bogies, has not been found very satisfactory, especially on account of maintenance difficulties. The new designs now proposed do not include any articulated rakes for this reason, but only combined railcars and trailers which can be coupled up together.

QUESTION 13. — *Are your railcars driven by a single employee? If so, is there any device to stop the car automatically if anything happens to the driver?*

On nearly all the railways, the railcars

are driven by one man. The exceptions are the Gafsa, Madagascar, Mozambique and Spanish Railways, where two men are always used, and Italy where two men are also used, except in the case of short distance runs worked by single-unit railcars.

In Czechoslovakia two men are only used in the case of the type D articulated rakes.

A device to stop the train automatically if anything happens to the driver is used on the Austrian railcars, on the types C and D in Czechoslovakia, on the Danish railcars, the TAR articulated rakes in France, the Indochinese railcars, and those of Norway, the Netherlands and Sweden as well as on some of the Spanish ones.

With some Administrations where only one man is used, there are no special devices and the guard has to stop the train if anything happens to the driver.

QUESTION 14. — *Do you use railcar vans and what are the results?*

The use of railcar vans is extremely limited.

Only the Swedish Railways report the use of railcar vans with a compartment for passengers, which are used with very good results for the transport of goods and luggage. The S. N. C. F. adopted motor vans to transport parcels, but the war ended this. Their power of 300 HP was not high enough to haul sufficient tonnage to be economical, and consequently the use of this method of transport was given up.

The *Italian State Railways* have 3 refrigerated motor vans in service for the rapid transport of fish, and 3 other vans specially designed for the transport of methane gas from the producer to the consumer.

Both these are quite special services, and no extension of the use of such vans is proposed.

A Renault motor van is used on the Indochinese Railways for short distance services.

QUESTION 15. — *Have you noted any advantages from the point of view of increased traffic due to the use of railcars on secondary lines? Do you use railcars on lines with very heavy gradients? If so, give details of the characteristics of these railcars and their utilisation.*

The introduction of railcar services on secondary lines has generally lead to an increase in the passenger traffic, the extent of which varies according to local conditions and to whether the previous services on these lines were or were not satisfactory.

None of the replies received was supported by actual figures. The replies agree that the use of railcars on secondary lines generally increases the average speed and number of services, gives greater comfort, and leads to lower operating costs.

We give below a table showing the increase in traffic found on the Annemasse - Geneva - Eaux Vives line of the *S. N. C. F.*, which is 6 km (3.7 miles) long, consequent upon the change over from 7 steam train units to 18 railcar units in January 1949 :

	Annemasse Station		*Eaux Vives station*	
	15 to 28 February 48	15 to 28 February 49	15 to 28 February 48	15 to 28 February 49
No. of tickets sold	876	3652	1327	4482
Passenger receipts	19 491 Fr. frs.	126 406 Fr. frs.	1 403.55 Sw. frs.	3 515.85 Sw. frs.

As regards the use of railcars on lines with very heavy gradients, the replies generally mention gradients of 25 $^{0}/_{00}$, occasionally 30 $^{0}/_{00}$, and very exceptionally 40 $^{0}/_{00}$, all of which are climbed by standard types of railcars without any special technical expedients.

The *Italian State Railways* are an exception however in operating the Paola-Cosenza line on which the prevailing gradients are 75 $^{0}/_{00}$ with railcars (this is a rack railway for operating by steam traction). On this line, the group ALn 56 railcars described under question 3 give a frequent service using single or twin railcars, and shortening the journey time by 50 % compared with the steam trains. No special measures are taken when working the service with railcars. All the axles are motor axles and can be braked on the rack. This provision which seemed necessary at the beginning was found superfluous in practice. The new RALn 60 railcars now under construction for the narrow gauge lines in Sicily where there are some gradients of 75 $^{0}/_{00}$, have no rack braking arrangement, but in addition to the usual compressed air brakes, are fitted with Westinghouse type motor brakes, which have proved particularly effective in the trials already carried out.

QUESTION 16. — *What is the working life of the different types of railcars on your railway?*

The replies to this question are not corroborated by sufficiently long experience, as generally, the first railcars built by the different Administrations are either still in service, have been altered to incorporate technical improvements, or have been taken out of service as being obsolete and not on account of their state of repair. The expected life of a railcar varies from 20 to 25 years.

The *Austrian Railways* distinguish however between the Diesel motor, the electrical equipment and the body, giving them lives of 20, 25 and 35 years respectively.

The *Belgian Railways* give 15 years as the life of the motor and equipment, 20 years for light types of bodies and 30 years for heavier types.

The *Czechoslovakian Railways* state the expected life as 14 years, it being the practice to turn railcars which have reached this age limit into trailers, thus extending the life of the body.

The *Swedish Railways* put the working life of railcars with wooden bodies at the low figure of 10 years or so, whilst expecting that of the new railcars under construction to be 20 years.

The *Damas-Hama Railway* limits the life of railcars to 12 years, this evidently referring to the motors; this short life is attributed to the fatigue of the motors owing to the difficult nature of the line and deficiencies in the technical services due to the difficulty of obtaining spare parts during the war and immediately afterwards.

The practice of making a periodic overhaul of a fairly extensive nature, which makes the motor or the bogies and bodies of railcars almost as good as new, followed by the *Italian State Railway* and *Belgian National Light Railways*, makes it possible to extend the life of railcars almost indefinitely.

On the last two railways, the withdrawal of different groups from service is not therefore determined by the deterioration of the motors, but merely by the fact that they no longer correspond in their structural design to the considerable technical improvements that are constantly being made.

QUESTION 17. — *What is your future railcar building programme?*

The programmes reported are as follows :

Austrian Railways. — Type TV 145 railcars the characteristics of which were described in the answers to question 3 are under construction.

Belgian Railways. — In the near future it is proposed to construct : 10 light bogie railcars, Diesel mechanical, similar to the type 553 already described, intended for tourist services; 50 simple Diesel mechanical railcars, which can be coupled together and haul a light trailer, and 20 light 4-wheeled trailers.

Danish Railways. — 4 type MK/FK articulated rakes and 20 Mo railcars are under construction, the characteristics of which were described under question 3.

S. N. C. F. — According to the programme for the standardisation of types as mentioned under question 3, France is constructing about 200 railcars of the standard 600, 300, 150 and 100 HP types.

Italian State Railways. — At the present time 100 railcars of greater power than the present types are under construction, the characteristics of which are comparable with those of the best types now in service, viz. :

	Railcars	
	new type	present type
Power HP	485	230 — 320
Maximum speed on the level km/h	130	110 — 130
No. of seats	80 — 90	56 — 72
Weight per seat kg	450 — 500	390 — 470
Space per seat m^2	0.55 — 0.56	0.40 — 0.50

These railcars are fitted with a single 12 horizontally opposed cylinder motor under the body in the centre, which is the most up to date arrangement as far as the comfort of the passengers is concerned (see fig. 37 and 38).

25 trailers are also being built for these railcars.

Finally 25 railcars and 5 trailers, mentioned under question 15, will shortly be delivered, intended for the narrow gauge lines in Sicily.

Norwegian Railways. — During the next 8 years provision has been made to built 20 type 6 railcars, 8 type 7 railcars and 7 of the type 8 articulated rakes already described.

Swedish Railways. — 50 railcars of the metal body type are under construction, and a further 100 will be ordered during the year.

The *Djibuti-Addis-Ababa Railway* has no programme for the acquisition of new railcars, as its policy is to put into service very light coaches hauled by Diesel-electric motor units.

In this way this Company expects to maintain the same speed of transport together with greater comfort for passengers and to have more seats available.

QUESTION 18. — *Have you any programme for the standardisation of types and components?*

The general tendency on the railways which have several types of railcars in service is to base their programme for future constructions on a limited number of types, according to those which have given the best results.

There is also a strong tendency towards standardising the most important components, such as the motors, suspension springs, traction and shock apparatus, drive and signalling gear, motor accessories, interior fittings, etc.

In connection with this general tendency, certain Administrations report difficulties of various kinds, not always due to technical reasons, which we do not consider it necessary to mention here.

In Italy the « Ente Nazionale Unifica-

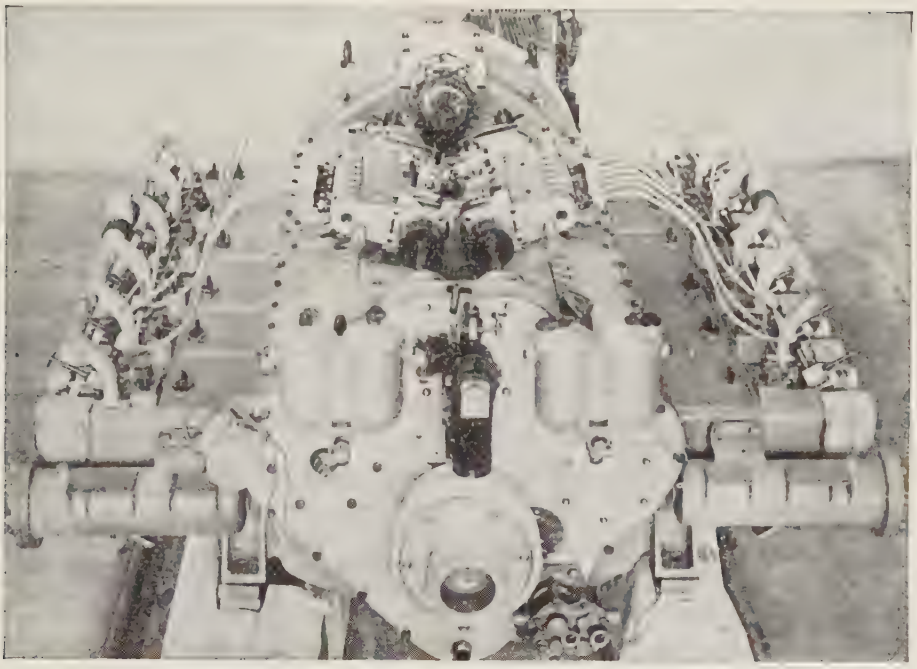


Fig. 23. — *Italian State Railways.* — Breda motor — 480 HP, 12 horizontally opposed cylinders.

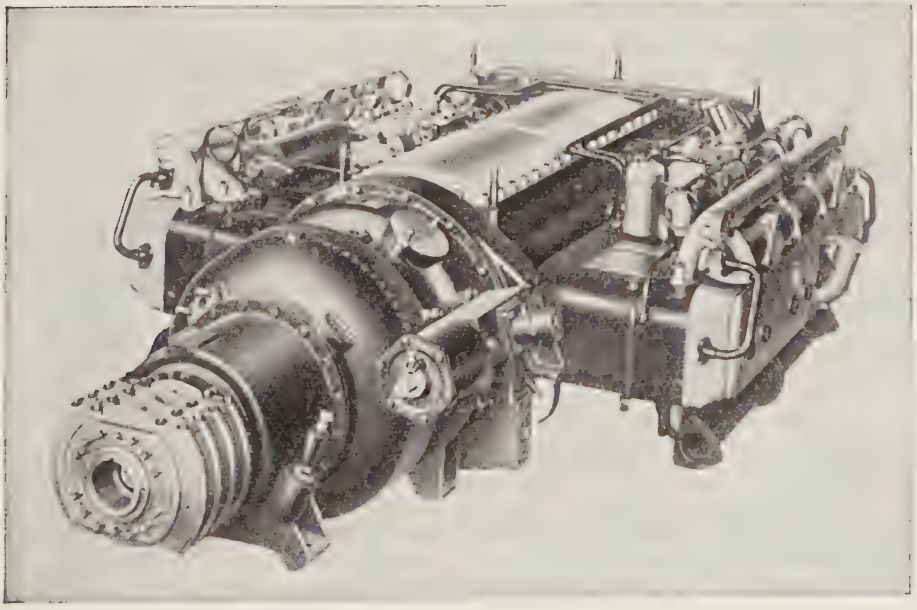


Fig. 24. — *Italian State Railways.* — OM Saurer motor — 480 HP, 12 horizontally opposed cylinders.

zione Materiale Ferro-Tramviario (UNIFER) » together with the U. N. I. has recently defined certain types of standard gauge railcars for main lines and for lines with little traffic.

The study of types for narrow gauge and local lines is under consideration, which will be followed by constructional details.

QUESTION 19. — *What is your opinion on the development of railcars, especially as regards : the power required and their utilisation with trailers?*

The *Austrian Federal Railways* consider it necessary on their system to use one or two trailers hauled by a 500 to 600 HP railcar so as to make the following possible :

a) rapid services on main lines with about 200 seats available;

b) running feeder trains to the main centres with about 300 seats available;

c) rapid and frequent services on secondary lines feeding the main lines, with about 100 seats available.

The *Belgian National Railways* foresee the almost complete suppression of steam locomotive operating due to the extension of electric traction and railcar services. In the case of the latter, their most appropriate use is on secondary lines. The railcars should meet the following conditions :

a) capacity about 100 passengers seated and 40 standing;

b) room for luggage;

c) maximum speed : 80 km/h. (50 miles) at least;

d) be able to be coupled up;

e) minimum power provided at least 6.5 HP per tonne to make sure they can haul a trailer or ordinary coach weighing about 20 t.

The *S. N. C. F.* recall the need to have available a sufficient number of trailers and railcars of such power that they can be used systematically and make it possible to adapt the composition of the trains of railcars and trailers to the variations in traffic.

The *Italian State Railways* expect further development in the future in operating railcars and the use of trailers not restricted to the secondary lines. The most suitable power for this purpose is considered to be 10 HP per ton of weight empty.

The *Norwegian Railways* foresee an increase in the power of railcars in step with the development of the use of trailers.

A similar development in the use of trailers where the power is 10 HP per ton is expected by the Spanish and Swedish Railways.

The *Belgian Light Railways* also consider that the power should be about 10 HP per ton empty weight in order to guarantee good acceleration, but they do not share the general opinion concerning the systematic use of trailers; in their opinion traffic requirements should be covered by frequent, fast services.

This idea is natural in the case of their characteristic services over short distances with frequent stops.

Considerations.

Twenty years of experience and evolution have confirmed the use of railcars as a suitable way of replacing steam traction within certain limits, in the case of the passenger services, thus making an invaluable contribution to the struggle against road motor transport.

Starting from the earliest designs, which were based on the limited requirements of economic operation on secondary lines with little traffic, on which railcars have proved their worth from the point of view both of economy and of improving the service offered to the public, they have received an ever wider field of application, and special types have even been designed to provide rapid through services on the main lines.

The demand for a larger number of

seats has been met by putting into service articulated rakes of two or more units, or by coupling several railcars together, or finally, the most recent solution, by the use of trailers.

From the oldest examples which might be said to have transfered to the railway many of the structural and functional characteristics of the technique of the automobile, and after having overcome a great many difficulties, progress has gradually resulted in the present types in which railway technique has once again taken the lead with its typical robustness of structure and strength of the components, which are no longer sacrificed to weight reduction, although somewhat lightened to have a certain affinity with automobile technique.

Solidity, comfort, weight, speed, power: these are the factors whose increase corresponds to the increase in the number of services operated by railcar.

The light types, however, which have also been perfected, have not been given up, in view of the advantages they offer on lines with little traffic.

All the motors are now of Diesel type, nearly all with direct injection, with a tendency towards high angular speeds, and in the more recent types, with supercharging. On the other hand there is no definite trend, not even in recent designs, as regards the number of motors for each unit, nor above all, as regards their siting. This latter problem does not seem to have benefited so far from experience gained from appropriate study or practical operation.

Notwithstanding this, however, certain countries, in which railcar services have developed more extensively, show a marked trend, both in the case of recent and planned constructions, towards siting the motors in the body rather than on the bogies, particularly as regards high-powered railcars used for fast journeys over long and medium distances.

In up to date railcars, the maximum speed lies in principle between 80 and 130 km/h. (50 to 81 miles), the weight per seat varying from 250 to 850 kg (551 to 1 874 lbs.), preferably being 350 to 500 kg (772 to 1 102 lbs.), the specific power — except in the case of the light types — lying around 10 HP per t (under full load), so that several trailers can be used.

As regards the drive, the mechanical system is the most popular; preselective and synchronised gears and hydraulic gear change are both favoured.

The daily user of the railcars generally lies between 300 and 350 km (186 to 217 miles) for the vehicles in service, which corresponds to 200 to 250 km (124 to 155 miles) for the total stock. Breakdowns are very few, and comparable with the average percentage for other methods of traction.

The increase in the average speed compared with steam traction is 25 to 35 % on the average, with peaks of 50 to 60 % and even 100 %.

The percentage of services operated by railcars compared with the total services operated by other methods of traction is, in the case of the most important Administrations concerned, about 25 %, with a tendency to increase.

The use of trailers is more or less general in the case of the most recent types, and generally does not reduce the maximum speed; acceleration on starting and the speed at which gradients can be climbed are hardly affected when the motor units have been well designed for the services in question.

As regards the possibility of coupling up and remote control, there is a marked tendency towards this, generally limited to two motor units, with one or two trailers if required; the use of articulated rakes is not being extended in the same way.

Normally the railcars are driven by one man only, except in the special case of articulated rakes or coupled units, when some Administrations employ a second man to look after the motors of the units behind the leading unit.

To stop the train if anything happens to the driver, safety devices are used by 50 % of the Administrations, whilst the others use two drivers or make the guard responsible for stopping the train in case of need, or else think safety requirements are met if the accelerator goes back to the minimum position or the motor stops as soon as the driver relinquishes control.

Railcars are not often used on heavy gradients, apart from the very interesting case reported by the Italian Railways where railcars are used on adhesion lines with gradients of 75 $^{0}/_{00}$.

Nor are railcars often used for carrying goods.

As regards the life of railcars, the most recent designs are estimated to have a life of 15 to 25 years, the tendency being to ascribe the upper limit to the body and the lower limit to the engines and equipment. Certain Administrations, in view of the rapid progress of technique, are going to transform, or have already transformed, their older types into trailers.

Confidence in the possibilities of the railcar as regards increasing the passenger traffic, obtaining economic operation, meeting the competition of the road, together with more frequent services, a higher average speed and greater comfort have all led to the progressive increase of this method of traction. This is shown by the programmes for new constructions in course of building or under investigation by most of the Administrations who replied to the questionnaire. These programmes are also inspired in principle by standardisation of the types of railcars and their main components.

The use of railcars has good prospects on most railways because they make a decisive contribution to speeding up the passenger services on the non-electrified lines, while at the same time making them easier, more complete and more economic.

As we have seen in the case of Diesel train locomotives, the non-European railways covered by the present report may find the use of railcars particularly opportune, in addition to the reasons mentioned, because difficulties of fuel supply, the characteristics of the lines and the equipment increase the advantages of railcars compared with steam traction. Some of these railways have in fact reported as factual evidence increases in the average speed of from 60 % to 100 % compared with those previously obtained with steam traction.

[625 .2]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION IV.

The comfort of passengers in coaches, railcars and electric motor coaches :

Sound proofing ;
Lighting ;
Heating, air conditioning, ventilation, thermic insulation ;
Upholstery ;
Running stability (type of bogie and suspension).

SUPPLEMENT TO REPORT (*)

by O. G. Weberg,
Ingénieur en Chef à la Direction Générale des Chemins de fer de l'Etat danois.

Since the completion of our report we have received replies from the French Overseas Railways and from the « Dienst der Staatsspoorwegen » in Bandoeng, and consider it desirable to present a supplementary report on the information furnished by these Administrations, despite the fact that some information on the Railways of Indo-China, taken from a reply received direct from the management, is already included in the report.

The information from the State Railways in Bandoeng relates to sixty carriages built during the years 1920-1940 for fast services (maximum speed 90 km/h.) on the Batavia Soerabaya line. As those carriages were partially destroyed during the war, the Administration points out that the information refers to the pre-war situation.

A. Sound insulation.

A. — *I. Carriages.*

French Overseas Railways do not use flexible wheels but « flock » is applied to body and floor panels. Rubber insertions between body and bogie are not used.

The Java State Railways have only used for reducing noise, rubber under and on the floor and in some carriages rubber between the body and the bogie.

In carriages which have had air conditioning, double walls and windows have shewn themselves advantageous not only for heat insulation, but also for sound insulation.

A. — *II. Railcars.*

French Overseas Railways do not use flexible wheels on stock now in service, but

(*) See *Bulletin of the International Railway Congress Association* for May 1950, p. 931.

some two axle railcars with resilient wheels will shortly be ordered for trial.

To reduce the noise of the motors use is made of usual mechanical devices with a direct injection Diesel motor, helical gears and a casing for the rockers.

Noise from the gears is reduced by using ground gears with helical teeth.

To reduce the propagation of noise inside railcars a rubber shock and vibration damper is fixed to the centre beam of the bogies and takes the pivot on which rests the body bearer.

The motor unit rests on the frame through rubber blocks, to damp noise and vibration from the internal combustion engines. There is no soundproofing of walls but the passenger compartment is separated from the motor compartment by a transverse corridor and toilet compartments.

B. Lighting.

B. — *I. Carriages.*

For electric lighting of carriages the French Overseas Railways use 24-30 V D. C. A dynamo of 25, 50, 70, 110 or 150 A, driven by belt from the axle recharges the batteries directly. The batteries are nickel-iron with a capacity of 80, 190, 250, 350 or 450 Ah. In each compartment or section, 1st or 2nd class, there are two 25 or 40 W incandescent lamps and in 3rd class one 25 W, the light is diffused. Reading lamps are provided in sleepers and semi-sleepers. Emergency lighting can be arranged by :

1) 1/2 lighting by coupling two vehicles;
2) emergency candle holders.

Except in 3rd and 4th class, where lighting is controlled by a single switch, it is possible for the passenger to switch on and off and reduce the lighting.

The lamps are protected by glass shades.

Blue night lights of S. N. C. F. type are used.

The Java State Railways have given the following information on the most modern sleeping cars :

1st and 2nd class coaches were provided with 2, 24 V, 75 A, dynamos and 2 Nife type batteries, 240 Ah capacity; the 3rd class had a 24 V, 110 A, dynamo and a 140 Ah battery. Batteries were driven by belt or cardan shaft, and the Administration has preferred the cardan arrangement. Each 1st or 2nd class compartment had 2 40 W lamps and a 6 W night light; reading lamps were 10 W. Corridor, bathroom and toilet compartment had 25 W lamps.

In 3rd class compartments 25 W lamps were used.

The dynamos and batteries are also used for the electric ventilators, taking 20, 24 or 35 W.

B. — *II. Railcars.*

The railcars of the French Overseas Railways have 1 800 W dynamos driven by pinion and tension controlled by a regulator. Cadmium-nickel batteries of 318 Ah capacity are recharged automatically on the vehicle.

Each first class section has two 25 W incandescent lamps and 2nd class one 25 W. Night lights are 24 V, 10 W and as on carriages are fitted with diffusers. De luxe railcars have provision for passengers to switch on or off or reduce the lighting.

C. Heating.

C. — *I. Carriages.*

The French Overseas Railways, which do not use steam heating, have given the following supplementary information on the Indo-Chinese Railways :

In Indo-China, certain de luxe vehicles (restaurant cars, sleeping cars, etc.) have air conditioning with electric heating battery which comes into operation for a part of the journey (on high-altitude lines).

The supply tension for the heating installations is 110 V and the installed power of the heating battery is 7 280 cal.-h.

This is on the basis of an outside temperature of + 4° C. (39° F.) and a maximum speed of 90 km/h.

In certain de luxe vehicles in Indo-China, air conditioning has been used. The characteristics of these installations are :

A. — Cooling : 18 000 frigories/h.;

B. — Heating : 7 280 cal./h.;

C. — Air intake for the whole carriage : 3 000 m³/h. (105 944 cub. feet per h.).

Summer temperature is adjustable to 24, 25 or 27° C. (75, 77 or 80° F.).

Winter temperature is adjustable to 17, 19.5 or 22° C. (62, 67 or 71° F.).

The energy necessary for air conditioning is provided by a dynamo on the bogie and by accumulators.

The French Overseas Railways state that electric roof ventilators, which can be adjusted by the passengers, are in general use on all vehicles running in Africa.

With regard to heat and sound proofing, the following arrangements are used :

« Flockage » inside the bodywork; insertion between outer and inner panelling of an insulating material, cork agglomerate, Isoflex, Alfol or I. B. R. glass wool; floor insulation is by agglomerate cork.

A sunshade is arranged over the roof.

Double glass windows of Athermic or Catathermic type must remain closed.

Third class carriages of the Java State Railways are equipped with electric ventilators ejecting warm air to the atmosphere. Fresh air is introduced through grills in the side walls of the vehicles. In 1st and 2nd class, a ventilator under the floor draws in fresh air through a dust filter and injects it into the upper parts of the compartments.

Air conditioning is effected in express trains by day in 1st and 2 nd classes, where a container with 24 blocks of ice is located under the coach and cold water is pumped through an air cooler over the corridor. Cooled air circulates through a ventilator into the compartments. The maximum capacity is 60 000 B. T. U./h. and during a 12 h. journey it is necessary to refill the container three times. Thermic insulation is by insulating material placed between double walls and « Calorix » double glasses have been used in fixed lights.

C. — *II. Railcars.*

Ventilation in French Overseas railcars is by air intakes arranged in both running directions, between the ceiling and the roof, and adjustable apertures in the compartments, with ventilators for use whilst standing.

The principle of thermic insulation has been abandoned because of the negative results obtained with railcar bodies.

In the colonies, Athermic or Catathermic safety glass is used.

D. Interior decoration.

D. — *I. Carriages.*

Carriage seats for French Overseas Railways are built as follows :

4th class : simple wood lath bench;

3rd class : coach arrangement with double back-to-back (half-backs) of wood laths;

2nd and 1st class : coach arrangement with double back-to-back seats, full backs with head rests;

1st class (long-distance) : coach arrangement with club seating with adjustable backs.

Upholstered seats have springs and hair, and according to the class and the colony, leather, Texoid or woven covers are used. Some seats which are convertible to beds or berths are in use.

Panelling is varnished teak or oak from floor to waist rail in 3rd and 4th class carriages in Indo-China.

Painted blockboard, Isorel or Plymax is used in all other cases.

The floors are duck-boards on wood in 3rd class, and rubber flooring in 1st class and de luxe cars in Indo-China.

Linoleum is used in all classes in other cases.

Sleepers or semi-sleepers have sliding doors to a corridor. Other coaches, all classes, are centre corridor type.

Two access doors are provided for each vestibule at the ends of the carriage, opening inwards.

Seats are facing, except in long-distance trains, which have adjustable arm-chairs.

Luggage racks and Venetian shutters are provided *in all* classes, curtains or blinds.

tables, ash-trays, mirrors, clothes hangers, *in 1st and 2nd classes only.*

Toilet compartments have W.-C. hopper, wash bowl, white enamel walls, mosaic floor.

Water tank of variable capacity without heating for W.-C. flush and wash bowl supply, and for shower when provided :

1st and 2nd classes : W.-C. hopper with cover and seat;

3rd class : W.-C. hopper with half-seat;

1st and de luxe : shower (one per carriage) ;

1st and 2nd class : soap dispenser, towel, toilet roll holder.

Urinals are not provided.

Floors of toilet compartments are dished, with a central drain.

Information on width, etc., of corridors of several coaches of Indo-China is already included in Tables IV and V of our report.

In a composite 1/2 class with kitchen and bar, for the Cameroons, the width of the central corridor is about 650 mm (25.6 in.) in 1st class and 550 mm (21.7 in.) in 2nd class, and the distance between the seats is about 700 mm (27.6 in.).

The Java State Railways have upholstered seats in 1st class; compartment and corridor floors have rubber covering; back covers are provided.

Second and third class seats are of rattan.

In third class sleepers two ladies compartments have sliding doors, the other compartments being open.

In all coaches there are two toilet compartments and in sleeping cars of 1st and 2nd class, bath rooms are provided. Second class compartments two berth, first class compartments for one passenger.

Each compartment has a wash bowl, mirror, lamp, shaving lamp, arm-rest, ash-tray and clothes cupboard.

The water tank for the washbowls and toilet and bath rooms is under the coach, and water pressure is maintained by compressed air. In the toilet compartments there are a mirror, ash-tray, soap dispenser and paper towels.

D. — *II. Railcars.*

In the higher class of the French Overseas railcars, there are three-position arm-chairs upholstered with springs and hair with hair-cord cover.

The fixed seats in the lower class are covered with rattan.

The following information has been received with regard to the arrangement of seats :

	de luxe	Express		Omnibus facing
		higher class	lower class	
Direction	same	same	facing	facing
Type	adjustable backs	adjustable backs	fixed	fixed
Width of central corridor, mm	410 (16 in.)	410 (16 in)	387 (15 in.)	387 (15 in.)
No. of seats	2 + 2	2 + 2	2 + 3	2 + 3
Width of seats	575 (22.6 in)	575 (22.6 in)	465 (18 in.)	465 (18 in.)
Distance between seats	—	—	450 (17.7 in.)	450 (17.7 in.)
Length taken, mm	920 (36 in.)	920 (36 in.)	1 500 (59 in.)	1 500 (59 in.)

The walls are faced with aluminium and the floor is blockboard covered with linoleum. The outer access doors are hinged, opening inwards. The compartments have blinds, ash-trays and photographs.

In the toilet compartments the walls are white enamel, the mosaic floor is damp and rot proof, dished, with a central drain. W.-C. flash and washbowl are supplied from a 150 l (40 galls. appr.) water tank;

in the lower class the hopper has a half seat. The following fittings are provided : liquid soap dispenser, towel holder, coat hanger, mirror, paper box, handrail at the side of the W.-C. and linen towels.

E. Stability of running.

E. — *I. Carriages.*

The French Overseas Railways carriages have Pennsylvania bogies, Indo-China type, standard type and model AOF with the frame resting on the axleboxes through 8 helical springs and a swing bolster on two longitudinal laminated springs.

Trains on the Java State Railways run at a maximum speed of 100 km/h. (62 m.p.h.) and the use of special type bogies has not been found necessary.

E. — *II. Railcars.*

French Overseas railcars do not have swing bolsters. Spring deflection is 70 mm (2.75 in.) under 4 tons load. Suspension is by laminated and helical springs. Silicon spring steel is used, water hardened at 900° C. (1 652° F.) followed by reheating to 450° C. (842° F.). Pull is shewn as 4 400 kg at 55 kg/mm² (9 700 lbs. at 34.92 t. per sq. in.). Rubber blocks are fitted under the bogie pivots, bearing surface 4 300 cm² (666.5 sq. in.) load 8 000 kg (17 637 lbs.).

When swing bolsters are not used, there are coil spring checks and laminated springs with silent-bloc fitting carrying rubbing plates mounted on the spherical contact at each end of the bogie bolsters.

Hunting movement is controlled by the side checks, which take 40 % of the load.

Maximum play in the axlebox guides is 2 mm (0.079 in.).

Two or three axled cars are not used.

Stability measurements have been taken with Hallade recorders.

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The following photographs, figures 47 and 48, shew a type of toilet compartment for women and children, provided in Danish State Railway carriages, mentioned in Chapter D, 3, 1 (p. 991/61) of the Report.

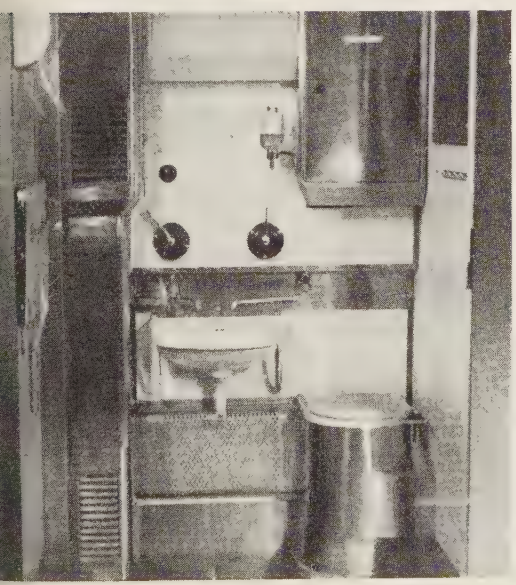

Fig. 47.

Fig. 48.

[625 .143 .4]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION II.

Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps ; determination of standard allowances.

SUPPLEMENT TO REPORT (*)

by O. Leduc,

Ingénieur en Chef au Service Technique des Installations fixes de la Société Nationale des Chemins de fer français.

After we had drawn up the Report for which we were responsible we received replies from 12 Administrations to the questionnaire sent to them; six of these gave positive information. They did not contain anything particularly new to add to the details given in our report. However we think it interesting to give a brief analysis of them below.

Belgian National Light Railways.

This Company uses 32 kg/m Vignole rails; their normal length is 18 m (59.1 ft.). They are laid on 20 sleepers (1.80 × 0.20 × 0.10 = 70.9 × 7.9 × 3.9 in.) and fixed by four coachscrews. The joints overhang (space between centre lines of sleepers : from joint 0.480 m [18.9 in.] from counter-joint : 0.688 m [27 in.], from the middle of the rail : 0.950 m [37.4 in.]) and parallel, except on curves where the amount out of line of the joints, which the use of short rails of 17.9 m and 17.8 m (58.7 and 58.3 ft.) was not able to make good, is corrected if necessary on the end of the curve by cutting a rail to the required length.

The fishplates are flat with lower flanges on the outside, with 4 (length 0.420 m = 16.5 in.) or 6 (length 0.650 m = 25.6 in.) holes; the fishplate surfaces which are not machined are given a cant of 1/3 and butt against the rail over their entire length.

The bolts used are 0.022 m (0.87 in.) in diameter, the fishplate holes 0.024 m (0.95 in.) and those in the rails 0.029 (1.14 in.). The amount of expansion allowed is 15 mm (0.59 in.).

The joint gap varies from 2 to 2 mm (0.08 in.) for differences in temperature of 10°, with a maximum of 13 mm (0.51 in.) (temperature below 0°) and a minimum of 2 mm (temperature above 40°). This empirical rule has given complete satisfaction.

Welded rails 54, 108 and 162 m (177,

(*) See *Bulletin* for February 1950, p. 127.

354 and 531 ft.) long have also been used (the 108 and 162 m rails on track with ballast up to the level of the rails). The welding is either aluminothermic or electric, and in the latter case they are supported by a larger sleeper making it possible to use 4 coachscrews. With these long rails, the standard fishplates are still used, but a packing of 6 to 8 mm (0.24-0.31 in.) is inserted in the joint between 5° and 25°. The National Light Railways Company considers that a length of 54 m (177.1 ft.) is the best from the point of view of the behaviour of the track, but on sheltered lines 72 m (236.2 ft.) long rails can be used.

Régie autonome des transports parisiens (Paris Métro-R.A.T.P.)

Fifty-two kg/m (34.94 lbs. per ft.) Vignole rails are used on the urban system and 46 kg/m (30.90 lbs. per ft.) on the SCEAUX line. They are 18 m (59.1 ft.) long and the RATP does not report the use of longer rails nor any investigations made to improve the classic type of fishplates.

On the SCEAUX line the joints vary from 0 m at plus 60° to 0.015 m (0.59 in.) at minus 18°, according to the law of free expansion with $\alpha = 10.5 \times 10^6$.

On the urban system they are regulated as follows :

a) on overground sections :

12 mm (0.47 in.) when the temperature is below 0°;

9 mm (0.35 in.) when the temperature lies between 0 and 10°;

7 mm (0.27 in.) at temperatures between 10 and 20°;

4 mm (0.16 in.) at temperatures above 20°;

b) on underground sections :

5 mm (0.197 in.) when the temperature is below 10°;

3 mm (0.11 in.) between 10 and 20°;

1 mm (0.04 in.) when the temperature is above 20°.

These rules are based on experience; the temperature does not vary much in the underground sections and as the track is brought up against the piers on curves, the joints can close without any inconvenience and all that is done is to correct abnormally large gaps by dividing the excess between adjoining joints.

Indochinese Railways.

The rails used are 30 kg/m (20.15 lbs. per ft.) Vignole, 8 and 12 m (26.2 and 39.3 ft.) long, laid on metal sleepers, standard fishplates with sole piece, and 4 holes.

As the temperature never falls below 15°, the joint gaps vary between 3 mm (0.11 in.) (8 m [26.2 ft.] rails) or 4 mm (0.16 in.) (12 m [39.3 ft.] rails) at 65° to 9 mm (0.35 in.) (8 m rails) and 10 mm (12 m rails) at 15°, with a tolerance of plus 4 mm and minus 2 mm (+ 0.16 in. and — 0.08 in.).

Tunisian Railways.

On the standard gauge lines this railway now uses 46 kg/m (30.90 lbs. per ft.) French Vignole rails or 49.560 kg/m (33.30 lbs. per ft.) American ones, identical to those used on the Algerian Railways already described in the Report.

The only points to be noted are :

a) the use of metal sleepers, with a flexible 4 mm (0.16 in.) rubber bearing plate, vulcanised hot. This arrangement, under trial since 1939 on a metre gauge line with 36 kg (79.36 lbs.) rails, has given complete satisfaction and reduces very appreciably the play at joints, and on the secondary lines, at any rate, the Tunisian Railways consider it is preferable to generalising the use of long welded rails;

b) the joints are always parallel on lines with heavy traffic, and the Tunisian Railways report that if staggered joints are satisfactory on lines where the speed is low (V = 50 km/h. [31.07 miles] at the most, axle load 12 t), they lead to a very

pronounced rocking of the stock at speeds of around 70 km/h. (43.50 miles);

c) broken fishplates are rare as a general rule; however the Tunisian Railways report that since Diesel-Baldwin locomotives were put into service, one of whose axles weighs 22.5 t, the number of breaks or cracks has become abnormal (6.500 on 165 km/h. [102.53 miles] of line in 1948) on an old line with 38.2 kg/m (25.67 lbs. per ft.) Vignole rails with 1.333 wooden sleepers per kilometer, fishplates with sole pieces 0.322 m (12.68 in.) long and 4 holes, overhanging joints (0.48 m [18.90 in.] from centre to centre of the sleepers at the joint). To remedy this, these fishplates have been replaced by 0.250 m (9.85 in.) fishplates, and extra sleepers laid near the joints (0.325 m [12.80 in.] between centres). In addition the radius of the curve connecting the horizontal base of the fish plate has been increased from 3 to 6 mm (0.11 to 0.23 in.). These measures have given good results. The cracked fishplates were repaired by electric welding and re-used on lines laid on metal sleepers where the sleepers can be laid closer together at the joints;

d) the standard length of rails is 12 m (39.4 ft.) (or 12 yards in the case of the U. S. A. rails), or 18 m (59.1 ft.) and so far welded rails have only been used at level crossings and on bridges. Their length varies from 36 to 60 m (118.1 to 196.9 ft.) with joint gaps at the end like those used with 27 m (88.6 ft.) rails. In addition three welded lengths of 100 to 110 m (328.08 to 360.9 ft.), have been laid through a station (encased track).

In the future the Tunisian Railways expect to generalise — at least on lines with heavy traffic (see *a*) above — the use of very long rails which, with the reserve that the bed is stable and the ballast of good quality and sufficient in quantity, will do away with hammer blows at the joints and the current maintenance thereof which represents 1/4 or 1/3rd of the cost of levelling the line with the 10 to 12 m (32.8 to 39.4 ft.) rails.

Emmenthal-Burgdorf-Thun Railway.

This railway uses 36 kg/m (24.20 lbs. per ft.) Vignole rails 36 or 48 m (118.11 ft.-157.5 ft.) long obtained by welding 18 or 24 m (59.1 ft.-78.8 ft.) rails together, with flat fishplates with four 0.520 m (20.47 in.) long bolts, with a very slight dihedral (1 mm [0.039 in.] deflection per 420 mm [16.54 in.]). The fishplate surfaces (rails and fishplates) have a slope of 1/2. 75 % of the sleepers used are wooden, 25 % metal. The rail fastening (57 wood sleepers 18 of which are anti-creep and 36 m [118.11 ft.] long) is by means of coachscrews or spikes (3 per rail) with simple bearing plates along the rails and « Mattbee » at the joints.

The bolts used are 21 mm (0.83 in.), the fishplate holes have a diameter of 24 mm (0.95 in.) and the rails 25 mm (0.98 in.). The expansion allowed is 13 mm (0.51 in.).

The rails are only laid at temperatures lying between 4° (joint gap 13 mm [0.51 in.]) and 22° (joint gap 7 mm [0.27 in.]) in the case of 36 m (118.1 ft.) rails; the gap closes at 45°. The expansion is taken to be linear with $\alpha = 9.2 \times 10^{6}$.

Rhaetian Railways.

This railway uses 25 and 30 kg/m (16.70 and 20.15 lbs. per ft.) Vignole rails, 12, 15, 30 and 36 m (39.3, 49.2, 98.4, 118.1 ft.) long, the latter lengths being obtained by welding together 15 and 12 m (49.2-39.3 ft.) rails; the fishplate bearings have a slope of 1/3. The sleepers used are generally metal with fastening by means of clips and bolts; wood sleepers are only used in tunnels, on metal bridges, and for insulated joints, in which case the rails rest on metal bearing plates with a slanted upper face 1/16, and are fixed (direct fastenings) by coachscrews or rigid or elastic spikes (T 7 spikes of the « Elastic Rail Spike Company »). 42 sleepers are used for a length of 30 m (98.4 ft.), 48 per length of 36 m (118.1 ft.).

The arrangement of the sleepers is the same at the joints whether they are welded

or fishplated : overhanging joint (340 mm = 13.39 in.) or preferably carried on double metal or wooden sleepers. In the first case the railway uses angle fishplates with extended webs, in the second case angle fishplates with metal sleepers and flat fishplates with wood sleepers, but in this case it is not possible to strengthen the joint with encasing sleepers, and it is expected that they will be replaced by angle fishplates acting as anti-creep devices. According to the importance of the case, 1 to 6 « Fair » anti-creep devices are used in the middle of long rails.

In general this railway considers that in comparison with 12 or 15 m (39.3-49.2 ft.) rails 36 and 30 m (118.1-98.4 ft.) rails do not lead to any savings in construction or maintenance, the reduced number of joints being compensated by the larger joint gaps in winter of those remaining, and the wear at the ends of rails, and of the rolling stock is increased. It should however be pointed out that the temperature varies between — 30° and + 50°, and that this is a narrow gauge line, with a thin bed, and consequently very light and therefore very sensitive to deformations.

ERRATUM

Bulletin for August 1950.

Report by Ch. HOFFET.

Question VI. — (15th Session, Rome 1950).

Pages 1636/285 — 1637/286. — TABLE I.

The text of columns 12 and 13 for the Numbers 17 to 21 must be altered as follows :

Columns 1		12	13
	.....		
17	.....	1070	USA Diesel-electric
18	.....	1120	Diesel-electric.
19	.....	1260	
20	.....	1510	
21	.....	1510	

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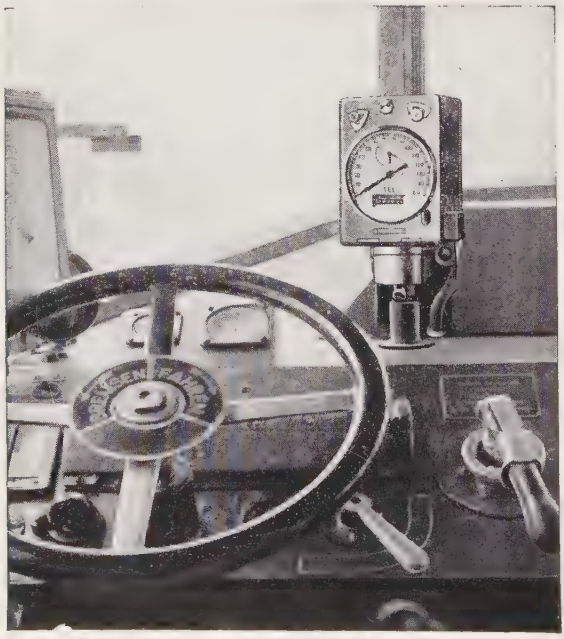

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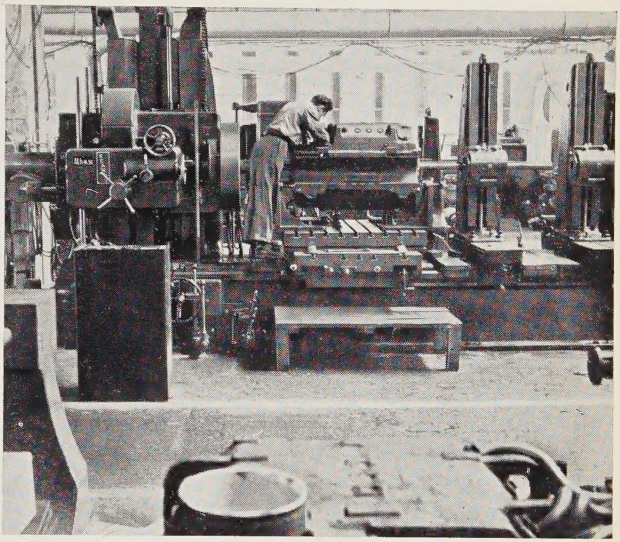

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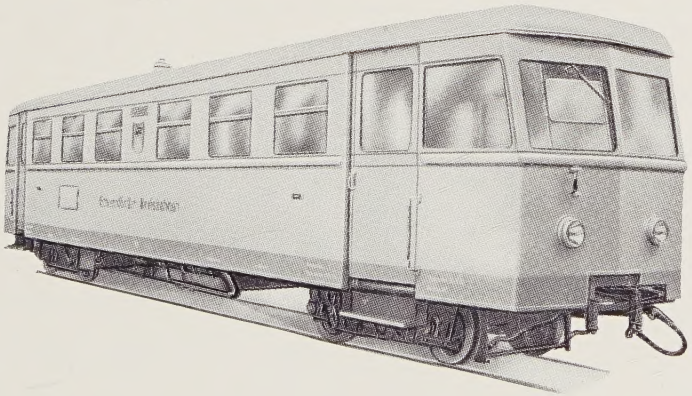

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